File Copy
PIBS 1599

STORMWATER QUALITY BEST MANAGEMENT PRACTICES

JUNE 1991

Ontario
Environment
Environnement

ISBN 0-7729-8478-6

STORMWATER QUALITY
BEST MANAGEMENT PRACTICES

Report prepared for :
Environmental Sciences & Standards/Water Resources
Ontario Ministry of the Environment

JUNE 1991

RECYCLABLE

Cette publication technique
n'est disponible qu'en anglais.

PIBS 1599
Log 91-2307-025

Fourth Printing

June 1992

STORMWATER QUALITY
BEST MANAGEMENT PRACTICES

Report prepared for:

Environmental Sciences & Standards/Water Resources
Ontario Ministry of the Environment

Report prepared by:

Marshall Macklin Monaghan Limited
Consulting Engineers Planners
80 Commerce Valley Dr.E.
Thornhill, Ontario

In association with

LGL Limited
Loiederman Associates Inc.

DISCLAIMER

FOREWORD

There is general recognition that urbanization can have adverse impacts on streams and other receiving water bodies. The resulting change in the hydrologic regime from increased stormwater runoff may cause flooding, streambank erosion and water quality problems such as increased pollutant loadings, temperature effects, baseflow reduction, habitat changes and groundwater impacts. Degraded watercourses in urban areas are very difficult and costly to restore. Therefore the mitigation of stormwater impacts must be addressed during the planning, design and construction stages of urban development. Previously stormwater management practice in Ontario dealt mainly with quantity issues such as downstream flooding and erosion. The Urban Drainage Design Guidelines addressed primarily quantity concerns. There is a need for a new and broader approach to stormwater management that would be based on all water and resource management concerns. This involves the integration of comprehensive resource management planning on a watershed basis with municipal land use planning and the use of tools such as conservation practices, source control and structural Best Management Practices (BMPs).

In order to provide guidance for implementing BMPs that could mitigate stormwater quality impacts the Ontario Ministry of the Environment initiated a project to develop a BMP design manual. Structural BMPs refer to techniques such as extended detention ponds, wet ponds, infiltration basins and trenches, vegetative systems e.g. grassed swales, porous pavement and water quality inlets. Although other North American jurisdictions have produced BMP design manuals and guidelines, their use in Ontario may not always be suitable because of climatic, topographical, political and other differences.

By means of a literature review, a municipal survey, a workshop with experts, and an analysis of the database of BMPs in Ontario this report has addressed the applicability of BMPs in Ontario. The report details a methodology for the integration of BMP planning into the municipal planning process, a BMP selection process and recommendations for the BMP design methodology. It provides estimates of BMP capital costs, maintenance costs and gives recommendations for research and monitoring studies. It outlines the approach and the work program necessary for producing an Ontario BMP design manual which will be done in a subsequent study.

Stormwater management is a multi-jurisdictional issue and the study was conducted with the helpful input of staff from several agencies including provincial ministries, conservation authorities, local municipalities, professional associations and consultants.
BMP technology is still evolving and there is a need to undertake studies of both existing and new BMPs to improve our understanding and knowledge of their performance and operation over the next several years. There is a need for innovative designers to develop better BMP designs and for reviewing agencies to encourage this by showing flexibility in applying agency criteria. However sufficient information exists for implementing BMPs and the report has compiled a lot of information that would be useful for current stormwater quality management studies.

ACKNOWLEDGEMENTS

This report was prepared for the Ontario Ministry of the Environment by Marshall Macklin Monaghan Limited in association with LGL Limited and Loiederman Associates Inc. The principal writers of the document were Mr. D. Andrews and Mr. G. Bryant of Marshall Macklin Monaghan Ltd. The project officer was Mr. J. C. P'ng of the Water Resources Branch of the Ministry of the Environment. The study team gratefully acknowledges the assistance of the following people and organizations in the preparation of this document :

Project Advisory Committee

J. P'ng	Ministry of the Environment
D. Henry	Ministry of the Environment
M. Seto	Ministry of the Environment
I. Kulnieks	Ministry of the Environment
L. Pella	Ministry of Natural Resources
B. Hindley	Ministry of Natural Resources
W. Wong	Ministry of Transportation
G. MacMillan	Association of Conservation Authorities of Ontario
S. Meek	Association of Conservation Authorities of Ontario
D. Keliar	Municipal Engineers Association
J. Tran	City of Scarborough
J. Falke	City of Mississauga
D. Mack-Mumford	Town of Markham
N. Mather	Urban Development Institute

Background Data and Information

D. Lynch	Regional Municipality of Ottawa-Carleton
A. Perras	Regional Municipality of Ottawa-Carleton
R. Kerkmann	City of Mississauga
M. Michalski	Michael Michalski Associates
A. Gemza	Ministry of the Environment
A. Lam	Fred Schaeffer & Associates

BMP Workshop

J. Marsalek	Environment Canada
P. Wisner	Paul Wisner & Associates
W. Snodgrass	Beak Consultants
T. Schueler	Metropolitan Washington Council Of Governments
M. Weaver	Ministry of Transportation

Technical Assistance

J. Imhof	Ministry of Natural Resources
M. D'Andrea	Ministry of the Environment
M. Jerrett	Ministry of the Environment
I. Murphy	Ministry of Transportation

Executive Summary

Concerns regarding the quality of stormwater runoff and its impacts on aquatic resources have been increasing for many years throughout North America. It is now generally recognized that stormwater must be addressed during the planning, design, and construction of our communities, in a different manner than in the past. In order to achieve development forms which meet our current needs while preserving and maintaining our natural resources for the future, it will be necessary to plan our actions in ways which recognize such things as water quality and quantity, linkages between surface and groundwater, and dependencies between physical and biological resources.

Processes and methodologies for this new type of approach are evolving rapidly in the Province. Terms such as "watershed planning", "ecosystem approach", "sustainable development", "no net loss of habitat", and "enhancement", are encountered in virtually every undertaking. In efforts to turn these guiding principles into actual applications, environmental planners, engineers, and scientists will have to make use of tools including source controls, conservation, land use control, treatment, and structural Best Management Practices.

It is this latter class of tools which is the focus of this report. Different sections of the report address the planning, selection, design basis, implementation and costs of structural Best Management Practices (BMPs). Structural BMPs refer to ponds, infiltration techniques, vegetative techniques, wetlands, and underground storage facilities, which are implemented as part of a development or as part of a remedial program to correct existing problems. The use of these tools, in conjunction with other options such as housekeeping practices, land use restrictions or limitations, conservation and enhancement programs, and source controls of pollutants will result in future development forms which provide for human needs while protecting the natural environment.

BMP Selection in the Context of Land Use and Environmental Planning

While the emphasis of this report is on stormwater BMPs which will address water quality problems arising from urban development, "water quality" has been defined quite broadly to include not only contaminants, but also baseflow, temperature, and groundwater impacts. It should be recognized that water quality cannot be isolated from water quantity, erosion, and habitat issues. All of these aspects are inter-related (changes in water quantity can effect quality, erosion, and habitat diversity). Effective BMP design will be based on all water and resource management concerns as opposed to water quality concerns only. In order for this to be achieved, the selection and implementation of BMPs is best conducted within the context of both watershed planning and urban planning frameworks.

A BMP selection process is presented which is intended to represent a top-down approach to water quality. Linkages to watershed planning and urban planning have been identified. Consideration of BMPs begins at the highest level (Watershed Plan and Official Plan) and continues through each subsequent planning level. The basis for BMP selection is tied to the current, and potential, receiving

water uses. The current, and potential, receiving water uses should be established through the watershed planning and urban planning processes. Once these are known, water quality objectives can be identified based on receiving water characteristics, and a BMP(s) selected to meet these objectives.

No one BMP type is preferred; every BMP has advantages and drawbacks. Therefore, the selection process has been designed on the basis of choosing from an arsenal of water quality improvement techniques based on water quality concerns, site conditions, capital and maintenance cost, and design experience with different BMP types. This is different than an approach which emphasizes the use of certain BMP techniques over others. The selection process outlined in this report recognizes that each watershed or sub-watershed may require different actions to address specific use concerns. The process also recognizes that in many instances more than one type of BMP may be required to protect a range of resources.

Recognizing the multi-use nature of water management concerns, the report recommends the use of continuous analysis for the design of water quality BMPs. On a watershed, or large master drainage plan scale, this could involve the use of relatively sophisticated models for surface and groundwater characterization, and biological techniques such as habitat suitability index models. These sophisticated techniques will not always be needed at the local site level, especially where guidance is available from basin-scale Watershed Plans. The term continuous analysis, not continuous simulation, has been specifically used in recognition of the possibility of using simpler methods for regional or local water quality analyses. The key intent is to ensure that long term climatological and hydrological information is used as the basis for design, rather than a generic or hypothetical set of conditions.

Study Conclusions

This study involved extensive consultation with many agencies and experts in the field, as well as a search of the existing literature. Technical conclusions have been summarized from experience with BMPs in Canada and the United States with special emphasis on conditions in Ontario. In addition, conclusions have been drawn with respect to the implementation of BMPs as recommended in this study.

Technical Aspects

1. Numerous studies indicate that BMPs can be effective in removing contaminants, and therefore their implementation should be pursued and encouraged.

2. No single BMP type can be universally recommended. In many instances combinations of BMPs will be required to address a range of concerns.

3. There is limited experience with some types of BMPs in Ontario, especially those involving infiltration or wetland techniques. Their use should be encouraged and monitored in selected areas.

4. The sediment which is trapped by BMPs will be contaminated and likely have some limitations on disposal options. BMPs are meant to concentrate contaminants rather than allowing them to spread throughout the ecosystem.

5. There is a seasonality of stormwater runoff, water quality concerns, and BMP effectiveness in Ontario. The effectiveness of infiltration BMPs in the winter and spring has been questioned and requires further research.

6. Groundwater contamination in infiltration BMPs is a prevalent concern due to the mobility of dissolved chlorides and nitrates. Their use should be carefully controlled in areas where water supply is a concern.

7. Dry ponds, which have seen widespread use for quantity control, are generally ineffective as a water quality BMP.

8. Wet stormwater ponds are not an all-encompassing solution to water quality problems. There are drawbacks associated with ponds (stratification, lack of baseflow augmentation, impact to surrounding environment) which must be recognized when selecting possible BMP solutions.

9. Vegetative BMPs are typically not effective enough to be utilized as the sole type of stormwater quality control in most development applications. They do however represent a valuable supplementary BMP which should be encouraged in conjunction with storage and infiltration BMPs.

10. Issues of aesthetics, safety, and liability arising from the implementation of BMPs can be satisfied by specific design features.

11. Ongoing maintenance and in some cases, periodic replacement, of BMPs is extremely important to ensure effectiveness. Lack of regular maintenance has been a primary cause of BMP failure.

BMP Planning and Selection

1. BMPs should be selected based on the potential uses of the receiver and the resources to be protected. Consideration should be given to downstream basin export, instream, and local water quality concerns in selection of BMPs.

2. Integrated Watershed Planning is the preferred means of defining uses desired of the receiver and hence the basis for BMP selection. Watershed Planning should become a requirement through provincial policy statements issued under the Planning Act or other mechanisms.

3. At the Watershed Plan level it is important that there be **confirmation** of the ability of structural BMPs to satisfy watershed goals (in conjunction with other options such as land use controls, conservation, and buffers). If the use of all options, including BMPs, does not satisfy the watershed goals, then "soft" BMPs such as down-zoning may be necessary.

4. Watershed planning must integrate water quality objectives with water quantity objectives if healthy aquatic ecosystems are to be maintained or promoted.

5. Potential areas for regional BMPs should be identified at the Master Drainage Plan level. Regional and local BMP performance criteria should also be identified at this level.

6. BMP performance criteria will vary from watershed to watershed, and may vary from site to site depending on local concerns.

7. In the absence of an up-to-date Watershed Plan the basis for BMP selection must be determined through pre-consultation with regulatory agencies.

8. Completion of Watershed Plans and Master Drainage Plans which address environmental issues as well as water quantity will reduce the time required for approvals because agencies will have a better understanding of the receiving water concerns. Local requirements can be reduced through the use of regional facilities.

BMP Design Criteria

1. Frequent storms are of greater importance in the design of BMPs than are extreme events.

2. Multiple storms, and snow melt/accumulation should be accounted for in the design of BMPs due to the seasonality of runoff in Ontario.

3. Continuous analysis should be used to size BMPs. Local analyses could be based on regional continuous analyses. Continuous analysis is preferred since it accounts for the entire range of storms, the seasonality of runoff, and multiple storm effects.

BMP Costs and Maintenance

1. BMP capital costs (Chapter 7), and BMP operational and maintenance costs (Chapter 8) have been identified in this report.

2. BMPs will not perform effectively if not maintained. Some BMP types require relatively frequent replacement.

3. BMP maintenance costs may be expensive, and cannot be ignored during the BMP selection process. These cost should be considered however in the context of the cost of eventual remediation required for watercourses which have not been protected.

RECOMMENDATIONS

1. Stormwater BMPs should be implemented using the BMP selection process outlined in this report.

2. The proponent should be responsible for construction of BMP facilities.

3. In new developments, monitoring should be used to ensure the effectiveness of stormwater quality measures. If a BMP is not shown to be operating as designed, corrective measures should be undertaken and effectiveness demonstrated prior to the municipality assuming the facility.

4. Municipalities should be responsible for BMP maintenance. The use of a stormwater utility should be investigated to pay for the long term maintenance of stormwater BMPs.

5. BMP studies should be undertaken at two levels. Demonstration studies designed to collect immediate information regarding BMP operation at existing or currently designed facilities, should be undertaken immediately. Comprehensive pilot studies which will involve detailed monitoring and operational testing of BMPs should be undertaken over the next five years.

6. Six infiltration BMP pilot studies and three wet pond BMP pilot studies should be undertaken to determine the winter/spring operation of these types of BMPs. The pilot studies should be based on BMPs designed in accordance with the recommendations outlined in this report.

7. Research/Pilot studies should seek to address:

   a) winter/spring operation of wet ponds and infiltration BMPs
   b) receiving water effects from dissolved versus suspended solids
   c) receiving water improvements from BMP implementation
   d) standard monitoring methods
   e) bio-accumulation of stormwater contaminants
   f) Canadian BMP design standards
   g) pollutant first flush on a watershed basis

8. An Ontario BMP design manual should be produced based on the findings of this study. An expert system version of this manual should be produced to increase BMP awareness among non-technical personnel, promote water quality education, and to demonstrate the linkages between planning and stormwater management.

9. Reviewing agencies should encourage innovative BMP designs, and be flexible concerning agency criteria. Since inter-agency conflicts can only be resolved through modified designs or modified criteria, agency inflexibility will cause lengthy and frustrating water quality approvals.

TABLE OF CONTENTS

Page #

LIST OF TABLES

Page #

LIST OF FIGURES

1.0 INTRODUCTION

1.1 Background

Environmental awareness has been steadily increasing over the past 20 years. The initial focus for water quality centred on point source pollution such as sewage treatment plants, and industrial discharges. Although point sources of pollution are being systematically reduced or eliminated water quality degradation still occurs in Ontario watercourses. This continuing degradation has shifted the focus on water quality from point sources of pollution to non point sources of pollution such as stormwater runoff from agricultural and urban land uses.

In response to urban water quality problems, various "Best Management Practices" (BMP) have been developed to assist in the protection of receiving waters. There is a need to clarify the term "Best Management Practice" since it has been used over the past several decades to describe conservation practices in agriculture, water quality structures, and green space planning. <u>In this report "Best Management Practices" specifically refer to water quality facilities such as extended detention and wet ponds, infiltration systems, constructed wetlands, and various vegetative practices</u>. There is a certain amount of overlap between BMPs in a planning context and BMPs in a facility context since vegetative practices are a type of BMP. A reduction in zoning density as a planning BMP is equivalent to the use of additional buffer strips as a water quality BMP. A glossary of BMP terms, and illustrations of different types of water quality BMPs are provided in Appendix A.

The use of BMPs has gained acceptance in various locations throughout the United States (Maryland, Denver, Florida, California, Virginia, Wisconsin, and New York). Although there have been some BMP designs in Ontario, there are no standard approaches to their selection and design. In addition, the applicability of BMPs in the Canadian climate is unclear.

In recognition of these shortcomings, the Ministry of the Environment is undertaking a two-phase project with the goal of developing a BMP design manual for Ontario conditions. This report provides the findings from a stormwater quality best management practices study which forms the first phase of the project. It involved a review of existing Ontario BMPs, an assessment of the applicability of BMPs to Ontario conditions, and an assessment of the potential for BMP integration into the Ontario planning process. The BMP design manual will be completed in the second phase of the project by means of a subsequent study.

1.2 Purpose of Study

Water quality control will become a significant part of stormwater management in Ontario. It must be recognized, however, that the other aspects of stormwater management, namely erosion and quantity (flood) control, are of equal importance. Water quality cannot be managed without considering water quantity and erosion concerns since they are inter-related. A change in water quantity can affect erosion, habitat, and water quality. All of these factors influence the functioning of a watercourse since it is a dynamic and self-regulating system.

The purpose of this study is to justify the implementation of urban water quality controls, assess any associated potential negative impacts, and integrate their selection/design with the existing erosion and water quantity criteria as well as the current planning process.

It is recognized that the implementation of urban water quality controls will require a period of familiarization on the part of reviewing agencies, developers, consultants, and contractors. Accordingly, the design of BMPs in Ontario will be an evolutionary process which can be expected to continue similarly to erosion and water quantity control design.

It is hoped that this report will provide a starting point for BMP design in Ontario, and serve as a catalyst to the implementation of water quality controls as a stormwater management requirement.

1.3 Study Objectives

There were seven main objectives identified in the terms of reference for this phase of the study. These objectives can be summarized as follows :

1) Draw conclusions on the effectiveness of BMPs for Ontario conditions based on existing data. Areas which require further research/monitoring are to be identified.

2) Outline the factors in an integrated approach to BMP selection and demonstrate how the BMP selection process can be incorporated into the planning process. Make recommendations on the implementation of the BMP selection process.

3) Prepare a framework relating pond design parameters to the different objectives of regulatory agencies such as the Ministry of Environment (MOE), the Ministry of Natural Resources (MNR), conservation authorities (CA), and local municipalities.

4) Prepare a database on BMPs in Ontario that documents the physical characteristics, design parameters and features, and existing performance data.

5) Outline the approach and work program necessary to produce a BMP design manual including a data collection program if required.

6) Develop guidelines for the operation and maintenance of BMPs.

7) Develop construction cost estimates and land requirements for BMPs.

1.4 Report Layout

The report is organize in the following manner :

- **Section 2** provides a literature review of existing BMP research and outlines the existing information on Ontario BMPs. The results from a municipal survey, which was conducted as part of this study, are also presented in this section. Conclusions on BMP effectiveness and applicability to Ontario are presented, as well as recommendations for research.

- **Section 3** details the approach to BMP planning in relation to watershed and urban planning. This section outlines the integration of the BMP selection process into the planning process, and assesses the applicability of the BMP planning process to retrofit developments.

- **Section 4** describes the context for the selection of BMPs, and the BMP selection process. This section also discusses the use of performance criteria in the design of BMPs and in the determination of their effectiveness.

- **Section 5** compares the effectiveness of different design methodologies with respect to water quality. This section recommends a preferred design methodology which is based on water quality concerns and BMP type. A framework is provided which relates reviewing agency concerns to design parameters.

- **Section 6** discusses the use of ponds as a single solution to all water quality concerns. This section also provides two examples of the integrated BMP selection process.

- **Section 7** provides projected capital costs for Ontario BMPs on a per unit basis. The use and cost of vegetation with structural BMPs is discussed, as well as the role of conservation as it relates to the cost of BMPs.

- **Section 8** describes the appropriate maintenance functions for BMPs. This section also estimates the projected frequency of maintenance and projected service life of each BMP.

- **Section 9** outlines the estimated monitoring costs for research projects and new developments. A work program is proposed for the development of an Ontario BMP design manual.

2.0 DOCUMENTATION

2.1 Literature Review

Contaminants in Urban Stormwater Runoff

Urban stormwater runoff has been identified as a significant source of the following pollutants: organic matter (BOD and COD), nitrogen, phosphorus, chlorides, heavy metals, suspended solids/silt, oil and grease, bacteria and temperature (Novotny et al 1985, Qureshi and Dutka 1979, Rippey and Rippey 1986). In addition, a variety of toxic chemicals of domestic and/or industrial origin are often found in urban runoff (Schueler, 1987). Depending upon the stormwater management technologies employed at a particular location, these pollutants can find their way into both surface and/or groundwaters.

Spatial variations in stormwater quality are largely a function of local weather conditions (total precipitation, frequency and duration of storm events, temperature), land use type (eg. industrial vs residential) and land imperviousness (U.S. EPA, 1983, cited in Livingston, 1990), as well as site characteristics such as topography and soil characteristics (Livingston, 1990), and other factors.

At any particular location, stormwater quality can also vary on a temporal basis. On an annual basis, the level of contamination of stormwater at a particular site is largely dependent upon climatic factors. At a finer scale, however, stormwater quality can vary significantly during a single storm event. This is the "first-flush" phenomenon and it is characterized by a relatively large percentage of the total storm pollution load being carried by a relatively small percentage of the runoff volume (Sartor et al., 1974; Miller, 1985, cited in Livingston, 1990; Weibel, 1964, De Fillipi and Shih, 1971; Hansen et al., 1973; Colston, 1974; Shaheen, 1975; and Wilber and Hunter, 1975). Not all urban runoff contaminants exhibit the "first-flush" phenomenon, however. In addition, the prevalence of the "first flush" phenomenon tends to decrease as catchment size increases.

Hydrological Changes Due to Urbanization

Urban development alters the hydrologic characteristics of a watershed (McCuen and Moglen, 1988; Schueler, 1987). The removal of natural vegetation and grading of the land eliminates both interception and depression storage. The covering of the land surface with pavement and concrete prevents infiltration, and hence, eliminates a third natural storage component (soil storage). Studies have shown that the decrease in infiltration resulting from urbanization has led to the gradual lowering of groundwater levels in some areas (Imhof, 1990; Planck, 1990; Waller, 1978 cited in Free and Mulamoottil, 1983). Reductions in groundwater levels create several problems including reductions in the available

groundwater for municipal use, and reductions in groundwater inputs into surface water systems (Imhof, 1990). This latter impact is particularly important because groundwater inputs are important to the maintenance of base flows in many streams and rivers and because groundwater effects on baseflows have important thermal effects on streams.

This decrease in storage increases the volume of surface runoff (more rainfall appears as direct runoff). Grading and impervious land surfaces decrease the hydraulic roughness of the land and result in higher runoff velocities, and thus, lower runoff travel times. The decrease in runoff travel time and increase in runoff volume increase the peak runoff flowrate.

In terms of water quantity, these hydrologic changes invariably lead to an increased frequency in downstream erosion and flooding. Prior to the implementation of stormwater management, elaborate man-made channel systems were constructed, and natural streams were channelized to convey the additional runoff volume and increased peak discharge downstream to prevent flooding and erosion from occurring. These systems were extremely costly, however, and thus were discarded in favour of detention storage systems. This signified the birth of stormwater management.

Stormwater management techniques, until recently, have focused on the control of peak discharge by means of "peak shaving". It had been thought that "peak shaving" would have additional benefits such as erosion control when it was first introduced (McCuen and Moglen, 1988). Currently, however, "peak shaving" is recognized as having the potential to cause more erosion than no stormwater management controls at all (McCuen and Moglen, 1988; Marshall Macklin Monaghan Limited and Beak Consultants, 1988). The control of peak flows increases the time of occurrence of near peak flows and velocities in the channel by keeping all of the runoff volume within the stream channel. An increase in erosion will occur if the controlled velocity is greater than the in-bank critical velocity for a longer duration than the uncontrolled velocity. In an uncontrolled situation the uncontrolled flow overtops the channel banks and the flow spreads out (the in-bank velocity does not greatly increase).

The utility of "peak shaving" for its main purpose of flood control has also been questioned (Marshall Macklin Monaghan, 1988). A modelling study of the Rouge River showed that the downstream aggregate controlled peak flow from local "peak shaving" stormwater management facilities could be the same as the uncontrolled aggregate peak flow. This could occur on a watershed basis due to the timing differences of uncontrolled peak flows from different parts of the watershed compared to the combination of near peak flows from "peak shaving" facilities. Therefore, it is recognized that without adequate planning "peak shaving" techniques are not beneficial on a watershed basis since they do not attempt to preserve the pre-development hydrological characteristics.

The historical absence of water quality control resulted from a lack of understanding on the significance of hydrologic changes associated with urbanization on water quality. Moreover,

there has been considerable controversy concerning how best to mitigate water quality concerns. Current research (Livingston, 1990; Imhof, 1990; Planck, 1990) suggests that the hydrologic changes associated with urbanization may detrimentally affect downstream areas and receiving waters, including the aquatic communities. Aquatic communities within streams are linked to characteristics of their riparian zones (Cummins et al., 1984). Hydrological changes caused by urbanization lead to changes in channel morphology which affect the riparian zone characteristics, and hence, the stream ecosystem structure.

As more knowledge has been gained, the mandate of stormwater management has expanded to include water quality, as well as erosion and flooding concerns. This has led to the development of "Best Management Practices" which are stormwater management techniques primarily designed to control water quality concerns. These techniques also have the potential to address both flooding and erosion concerns. The integration of flooding and erosion concerns with "Best Management Practices" represents an improved stormwater management system. Watershed Planning is required to efficiently implement these BMPs since no stormwater management technique is universally applicable.

Best Management Practices

The term BMP (Best Management Practice) used to be synonymous with street sweeping and catch basin cleaning for pollution control. Research (Novotny, 1985, Pitt, 1985) has indicated, however, that both catch basin cleaning and street sweeping are ineffective for pollution removal (<15 % removal).

The focus for best management practices has since shifted to the use of structural techniques such as wet ponds, wetlands, extended detention ponds, infiltration techniques, vegetative filters, and planning techniques such as lower density zoning, buffer strips, and green space to mitigate water quality degradation.

Nationwide Urban Runoff Program (NURP) Studies

Considerable research has been conducted on the design and effectiveness of BMPs in the United States (Whipple and Hunter 1981, Randall 1986, Nix 1985,1988, Schueler 1985,1987, Driscoll 1986,1988, Roesner 1988, Jones 1988, Ferrara and Witkowski 1983, Urbonas 1988, Harrington 1988, Hartigan 1986,1988, Shaver 1988). The Nationwide Urban Runoff Program sponsored by the U.S. Environmental Protection Agency gave impetus to much of this research (U.S.E.P.A., 1983).

NURP funded 28 separate runoff studies from 1979 to 1983 costing in the order of 30 million dollars. These field studies were distributed across the U.S. based on specific selection criteria. A major objective of the study was the acquisition of data to characterize problems, evaluate receiving water impacts from urban runoff, and evaluate management

practices. The NURP study concluded that wet ponds, recharge devices, grassed swales, and wetlands were beneficial for water quality mitigation. Street sweeping and dry ponds were determined to be ineffective for pollutant removal. A summary of different BMP removal effectiveness from the NURP study is presented in Appendix B of this report.

Several potential disadvantages of BMPs were identified from the NURP study such as the impact of long-term sediment accumulation and its toxicity, the relationship between pH and heavy metals loading and their toxicity (acid rain effects), and the adverse environmental impacts of urban runoff on wetlands.

The potential disadvantages of BMPs, combined with conflicting views of jurisdictional responsibility, and uncertainty regarding the winter operation of BMPs, have impeded the implementation of BMPs in Canada.

Groundwater Contamination

The issue of groundwater contamination through recharge of urban storm water is one potential disadvantage of a BMP. This is a serious concern because contaminated groundwater can be expensive to treat, and because contaminants, once in the ground water, can persist for decades (depending on the nature of the contaminants and groundwater flow rates). In addition, contaminated groundwater eventually contaminates surface waters and, by doing so, can result in degraded aquatic ecosystems.

One of the NURP studies in Fresno, California, monitored 5 of their 86 recharge basins. Salo et al. (1986) discovered that the top soil layer contained elevated lead levels which would classify the soil as hazardous waste. The lead levels quickly decreased with soil depth, and the study concluded that there were no adverse effects on groundwater resulting from recharge of storm runoff. It was noted, however, that these results were site specific based on the land use, soil type, and depth to groundwater.

There is a general lack of groundwater monitoring studies with respect to contamination from BMPs. This stems from the fact that discharge from BMPs into the groundwater regime is dispersed, and hence, its overall quality is not easily quantified.

Sediment Contamination

Another potential problem is the accumulation of toxic sediment in BMPs. Several studies have documented contamination of sediments by stormwater runoff (Salo et al., 1986, Rowney et al., 1986). Most of the sediment quality studies indicate that the soil quality is stratified in BMPs such as wet ponds and infiltration basins. The first layer of soil (0-20 cm) contains deposited material, which is polluted (lead, copper, zinc, chlorides, and organic components). The second layer of soil (>20 cm) remains unpolluted. Although the first

layer of sediment usually exceeds M.O.E. Open Water Disposal Guidelines (lead and chlordane, (Salo et al., 1986), lead, zinc, copper, TKN, Ammonia, and COD (Rowney et al.,1986), barium and chlorides, (Kerkmann, 1990)), none of these studies were able to document adverse impacts on the surrounding environment. The impact of the sediment is site specific, depending on the existing ecosystem, depth to groundwater, natural soil characteristics, vegetation, etc.

Other studies (Free and Mulamootil, 1983) have shown that the stormwater can alter sediment characteristics and that changes in sediment characteristics can affect the aquatic ecosystem structure. In particular they found changes in the benthic communities associated with stormwater derived increases in organic pollution.

Data on sediment from Lake Aquitaine in Mississauga, Ontario (Kerkmann, 1990), suggests that the sediment may be used for clean fill, and is not a registerable waste. The report also indicates, however, that the sediment cannot be used near vegetation or groundwater wells due to its high salt content.

Research at a pilot Ultra-Violet (UV) disinfection facility in London (Kelleher, 1989) has indicated that the Fanshawe beach sediment is highly contaminated with bacteria. The continual re-suspension of sediment by swimmers and groundwater springs has been noted as being partially responsible for beach closings at this location. Hence, sediment contamination can present serious problems.

Weatherbe, Marsalek and Zukovs (1982) detected organochlorine pesticides and PCBs in water and sediment samples in a study of runoff from two urban residential areas. At a Burlington site, 24% of the PCBs and 39% of the pesticides were found to be transported by solids. Although the sampled urban runoff was contaminated, the effect of urban runoff on the Great Lakes as a whole was not deemed significant enough to justify the control of pollutants in runoff on an across-the-board basis.

Wiggington et al.(1986) studied the potential accumulation of cadmium, copper, lead and zinc in the soils of roadside grass swale drains that had been receiving urban stormwater runoff. The study concluded that the effects of storm water runoff on the swales were insignificant. A review of the pollutant accumulation data, however, indicates that the lead concentration in the soil taken near two of their three sites exceeded the Ministry of the Environment's decommissioning clean-up guidelines for lead.

Climate Effects

The applicability of U.S. BMP research in the Ontario climate has been questioned due to potential operational problems in the winter (frozen and/or saturated soil conditions, and ice conditions in ponds).

The majority of research into infiltration BMPs has been performed in temperate climates (Shaver, 1986, Salo et al, 1986). Some research has been done in colder climates such as Rochester, New York (Murphy et al., 1981). Murphy's research indicated that porous pavement operated without problem throughout the winter, and that no structural degradation occurred although the pavement was subjected to 100 freeze/thaw cycles.

Contaminated urban snow and street de-icing salts are recognized as additional pollutant sources in the Canadian climate. Zinger (1988) sampled snow collected from 3 sites in Montreal for 28 routine parameters. The analysis concluded that the quality of snow varied considerably according to the land use in the sampling area and the length of time the snow had remained on the streets. The quality of used snow was worst from the downtown core, then commercial areas, and finally residential areas. The primary pollutants determined in the snow were chlorides, suspended solids, and lead. The analysis of heavy metals concluded that there was a risk of bioaccumulation via benthic organisms. The effect of the used snow on the receiving water could not be determined for numerous reasons (swift currents, sewage outlets).

The high levels of lead in urban snow are linked to emissions from car exhausts. In 1982 car exhausts accounted for 61 % of all sources of lead. The introduction of catalytic converters, and the subsequent elimination of lead from gasoline, have resulted in a 50 % reduction in lead emissions from car exhausts (Metro Toronto RAP, 1990). This reduction in emissions will result in lower lead levels in urban snow.

Wetlands

The use of wetlands for urban water quality enhancement has received considerable recent attention. Interpretation of studies which have examined the value of wetlands for stormwater treatment is difficult due to differences in wetland types and stormwater characteristics (Stockdale, 1986a; Stockdale, 1986b; Chan et al., 1982; Harper et al., 1986; Kutash, 1985 cited in Livingston 1990).

The majority of emphasis has been on the use of constructed wetlands, as opposed to existing natural wetlands, since stormwater can have detrimental impacts on the ecosystem in natural wetlands (Hammer, 1990). In Maryland, there are strict regulations that limit the use of natural wetlands for stormwater management (personal communication with R. Claytor, 1990).

Constructed wetlands have gained attention due to their potential for nutrient uptake (Adams and Dove, 1984; U.S.EPA, 1983). Oberts (1982) found a strong inverse relationship between pollutant loadings and the percentage of the watershed in wetlands. Novotny (1984) concluded that wetlands were effective during the "active" wet season (May to September), but a potential source of nutrients in the dormant season due to the leaching of dead vegetation in the wetland. Martin (1988) also indicated that wetlands cycle

nutrients and recommended that research focus on minimizing this cycling.

Research conducted by Bayley et al. (1986) in southern Ontario suggests that when wetlands are used in a BMP, a pulse of high sulphate (and high Ca/Mg/pH) water may be released downstream in the spring and possibly in the fall. Research in a Florida wetland (Martin, 1988) indicated that pulses of zinc captured from previous storms were being released downstream. These pulses could be harmful to sensitive organisms in downstream water bodies and should be researched.

The hydrologic characteristics of wetlands under frozen soil conditions were researched by Roulet and Woo (1986). They studied a wetland in the North West Territories for 2 years. Their analysis concluded that no infiltration occurred in the wetland during the spring, and that spring runoff flowed over the surface of the wetland. The lack of runoff regulation was attributed to the frozen soil conditions. Even when thawing began in the spring, the high specific retention of peat limited the absorption of additional water.

Livingston (1990) concluded that wetlands have great potential to help resolve stormwater management problems, but that more information is needed to ascertain the possible effects of stormwater on wetlands and their flora and fauna. Little is known about the potential for bioaccumulation of heavy metals or other toxics commonly found in stormwater. This emphasizes the need for wetlands monitoring to determine the relationships between design variables, pollutant removal efficiency, and ecosystem health.

Aquatic Ecosystems

Before an assessment of the advantages/disadvantages of different BMPs can be made, it is essential to understand all of the impacts of storm water and storm water management systems on aquatic systems. The following sections provide a brief overview of the potential physical, chemical, biological, and hydrological effects of stormwater and different stormwater management practices on aquatic systems. It does not provide the eco-physiological basis for these effects, nor does it necessarily relate certain physical changes (eg. channel widening) to actual effects on particular aquatic species or to changes in the riparian zone (vis a vis Cummins et al. 1984). To do so is possible, but is beyond the scope of this report. By inference, the lists focus largely on effects of changes in the aquatic environment on aquatic organisms (fish, etc) and less so on more visible wildlife such as waterfowl, other birds, small mammals, etc. These other forms of urban wildlife are now being recognized as important features of urban wetland systems, not only aesthetically, but also as important components of healthy aquatic/riparian zone ecosystems.

It is important to recognize that the physical changes to aquatic systems resulting from, for example, channelization, changes in natural hydrology, and thermal changes, can have vast effects on the biological community. By changing the biological community, a system's "balance" is altered and its ability to process nutrients (for example) is changed (nutrient

cycling/spiralling). In this way, without actually changing nutrient inputs, it is possible to convert a "clean" system to a visually "polluted" one.

Aquatic Ecosystem Historical Perspective

Prior to the introduction of stormwater management, drainage activities focused on maximizing the rate at which stormwater was removed from urban areas. This was an era characterized by the creation of impervious urban landscapes, channelization of natural river/stream channels and construction of oversized storm drain systems. These practices, when combined with the common practice of "improving" (landscaping) natural areas (especially "wet" areas), effectively resulted in significant changes to watershed hydrology which, in turn, led to degradation and impairment of the characteristics and function of aquatic ecosystems in urban areas (Imhof 1990; Planck 1990). Simply stated, it was a period when, to a large degree, the linkages between (alterations to) watershed hydrology and the functional characteristics of aquatic ecosystems was poorly understood. It was also a period when groundwater management was ignored, especially as related to the impacts of reduced infiltration rates on groundwater quantities and subsequent impacts on the maintenance of baseflows in streams, wetlands and other bodies of water (Imhof 1990).

Stormwater management was introduced as a measure for flood and erosion control, and up until recently, stormwater quality control was considered only peripherally. Historically, stormwater was not considered polluted, and in most circumstances, the issue of a healthy environment was considered impossible in the face of development (which led to the view of " fish or people"). Hence, the potentially serious polluting effects of stormwater on the water quality in receiving water bodies (and in groundwater) were not considered.

Recently, water quality aspects of stormwater management have receive significant attention, and our perceptions of "appropriate" stormwater quality management strategies have changed. Initially, stormwater management structures, when linked to urban lakes and/or reservoirs, were viewed as a means of maintaining low flow augmentation. One of the (perceived) benefits of low flow augmentation was "pollution dilution". As such, it was an approach with considerable popular appeal since it was a low-cost "solution" to urban pollution problems which conveniently eliminated the need for "expensive" point-source pollutant controls. Unfortunately, it was based on an "out of sight, out of mind" philosophy which justified exporting one's pollution problems to where they could not be seen.

The control of erosion and sedimentation has been a concern in urban stormwater management for a number of years. However, this concern was based on the implications of erosion and sedimentation on maintenance costs and property protection. Little attention was given to its importance related to a "healthy" (functioning) aquatic system, stream channel morphology, or loss of our topsoil resources.

Only in the last 5 years have we started to examine the quality aspects of stormwater management practices from an ecosystem-based (defined in Appendix A) perspective. This

change in approach is based upon a recognition of three key facts: (i) water quality objectives must consider all parameters, physical and chemical, which are important to aquatic life and to human health; (ii) that maintenance of "natural" hydrologic cycles is important to the minimization of erosion and sedimentation problems and the minimization of groundwater and stream baseflow problems; and (iii) that maintenance of "natural" river and stream system biophysical processes, and habitat diversity is critical to the maintenance of "healthy" aquatic environments (i.e. channelized systems are not "healthy" systems).

Impacts of Hydrologic Changes to Aquatic Ecosystems

The hydrologic changes described above in the section entitled "Hydrological Changes Due to Urbanization" impact aquatic ecosystems, in large part, by changing stream geometry (Schueler, 1987). The resulting changes in physical characteristics (or geometry) of the receiving waters, effectively alter their suitability as habitat for naturally occurring species. All species which utilize or are found in aquatic systems have specific habitat requirements. Sensitive species tend to have fairly narrow habitat requirements. Less sensitive species can tolerate relatively large changes in their physical and/or chemical habitats.

The habitat requirements of many aquatic species can usually be described in terms of:

- depth of water
- velocity of water
- substrate
- temperature of water
- vegetative cover
- water chemistry (e.g., oxygen, CO_2, pH, alkalinity)
- tolerance to contaminants
- availability of suitable food organisms

It is important to recognize, however, that the habitat requirements of many species (birds, mammals, fish) vary seasonally and with life stage. Therefore, strategies for protecting the habitat requirements of a particular life stage of a particular species while ignoring other life stage requirements will invariably lead to the loss of that species from that system.

Examples of the physical changes (to stream geometry or channel characteristics) resulting from the hydrologic changes described above include:

- channelization
- widening
- straightening
- changes in grading/slope
- changes in pool/riffle sequence
- destabilization of channel morphology (bedload, accretion/incisement rates, channel movement)

These physical changes result in:

- reduced habitat diversity (increased homogeneity)
- altered seasonal flow and water levels patterns
  (de-watering of key habitat areas at some times of year
  flooding of key habitat areas at other times)
- reduction in cover due to loss of streambank vegetation
- changes in mixing characteristics - oxygenation/thermal mixing
- altered thermal characteristics

Many investigators have examined changes in the ecology of streams associated with urbanization. Several studies (Dietemann 1975; Ragan and Dietemann 1976; and Klein 1979) cited in Schueler (1987) documented reductions in abundance and in fish community diversity in developed watersheds. They also found that sensitive species often disappeared.

Impact of Thermal Changes to Aquatic Ecosystems

The process of urbanization typically leads to reductions in groundwater recharge rates (McCuen and Moglen, 1990). Groundwater is critical to the maintenance of base flows and to buffering thermal changes in many aquatic systems (Klein and Gracie 1980; Planck 1990). According to Klein (1979), (cited in Klein (1980)) stream water temperatures are primarily controlled by stream bank shade and base flow volume. Consequently, changes in baseflows associated with urbanization inevitably lead to changes in habitat quality. This, in turn, affects the structure of the affected aquatic ecosystem.

Much of the attention regarding the effects of reduced base flows associated with urban development has focused on elevated stream temperatures during summer months (Klein 1979, cited in Klein and Gracie 1980). Elevations in summer temperatures associated with urbanization and reductions in base flow are known to have had negative impacts on many aquatic communities, particularly coldwater communities. However, Pluhowski (1970), also cited in Klein and Gracie (1980) found that base flow reduction contributed to reduced winter water temperatures and increased risk of freezing, and concluded that reduced winter temperatures could affect stream community structure.

Virtually all of the biological and chemical processes which are fundamental to the structure and functioning of aquatic systems, but which cannot be specifically related to physical habitat structure, are temperature dependent. Therefore, changes in the thermal conditions in a stream can have marked impacts not only on community composition, but also on productivity.

Pollutant-Related Impacts to Aquatic Ecosystems

Many of the water quality problems associated with urban stormwater have been discussed in an earlier section (Contaminants in Urban Stormwater Runoff). The following lists describe the potential effects (or mechanisms of effect) of the each of the major pollutant categories on aquatic communities. No attempt has been made to differentiate between the effects of these pollutants on different ecosystem components (i.e.,different trophic levels - bacteria, phytoplankton, zooplankton, benthos, aquatic macrophytes, fish) because a complete listing is beyond the scope of this report and because adequate summaries are available in a number of common texts (e.g.,Warren 1971). Furthermore, no attempt has been made to quantify the magnitude of the impacts resulting from each of these categories of pollutants because categorical generalizations are not possible. For example, the consequences of moderate silt loads may be serious in one situation and inconsequential in another. Assessment of the probable impacts of pollutants on a particular system must be assessed on a case-by-case basis.

a) silt

- physical destruction of habitats (spawning beds, etc)
- changes in water quality (turbidity, nutrient effects, etc)
- effects on primary and secondary productivity
- effects on benthic organisms
- physical damage to certain species (gill damage)
- suspension of nutrients/contaminants
- see also Alexander and Hansen (1988); Jones and Redfield (1984); Free and Mulamootil (1983)

b) nutrients - eutrophication effects

- water clarity
- oxygen limitation
- odour
- aesthetic appeal
- algal blooms
- nutrient spiralling rates
- see also Jones and Redfield (1984); Walker (1987); Rippey and Rippey (1986); Free and Mulamootil (1983)

c) metals

- bioaccumulation in desired species (eg fish, waterfowl)
- safety for human consumption
- sublethal effects on aquatic ecosystem

- trapping/no trapping in wetlands
- Rowney et al. (1986); Adams and Dove (1984); Maryland Dept. of the Environment (1984)

d) chlorides

- effects on ion-/osmoregulation
- Free and Mulamootil (1983)

e) organic matter

- oxygen demand - BOD, COD
- putrefaction/odours
- Rowney et al. (1986); Adams and Dove (1984)

f) bacterial contamination

- affects productivity, ecosystem health, and human use
- Adams and Dove (1984); Qureshi and Dutka (1979)

g) other contaminants - contained/not contained

- bioaccumulation in desired species (eg fish, waterfowl)
- effects on human consumption
- sublethal effects on aquatic ecosystem
- trapping/no trapping in wetlands

h) loss of wetland and wetland habitat
- loss of critical habitat for fish, waterfowl, other birds, and other wildlife
- reduction in sediment trapping capacity
- reduction in flow moderating effects
- reduction in ability to improve water quality
- nutrient removal
- contaminant uptake
- reduction in temperature moderating effects

Receiving Waters Use (Recreation)

One of the first Canadian stormwater quality programs originated in the Ottawa area (Rideau River Stormwater Management Plan). The objective of this program was to control stormwater quality to prevent beach closings in the downstream sections of the Rideau River. In Maryland there is not the expectation of using the receiving waters for body contact recreation. In Ontario, fecal coliform is currently used as the water quality indicator for body contact suitability (In 1986 the U.S.E.P.A. issued a revised bacterial indicator,

E. coli, which is a subset of fecal coliform).

Monitoring of coliform levels, as well as other parameters has been carried out in the Ottawa-Carleton ponds since the late 1970s. This monitoring is discussed in further detail in Section 2.3 and Appendix C.

Coliform bacteria in urban runoff was noted as a significant problem during and immediately after storm events in most rivers and streams by the NURP study (US EPA, 1983). Qureshi and Dutka (1979) monitored the microbiological quality of urban storm water at three different sites in Ontario. Microbial densities were determined to be as high as dilute raw wastewater. The monitoring suggested that snow in urban areas may harbour and preserve micro-organisms which eventually reach storm sewers and rivers. Infiltration water, sediments, and snow were identified as the three principle sources and carriers of micro-organisms. No relationship was found between rainfall intensity and bacteria concentrations (no "first flush") indicating that treatment of a portion of storm runoff would be ineffective.

The association of bacteria with sediments (Qureshi and Dutka, 1979) would indicate that retention of storm runoff should decrease bacteria levels in the water itself. Most of the ponds in the Ottawa-Carleton area were designed to retain storm runoff for a period of 72 hours, after which the pond contents would be allowed to drain to the watercourse. Whipple and Hunter (1981) noted an order of magnitude reduction in bacterial counts after 32 hours of detention. Randall et al (1982) also noted reductions in total coliform levels after 24 hours of detention.

Research on an Ultra-Violet (UV) test facility at Fanshawe Beach in London (Kelleher, 1989) indicated that bacteria laden sediment represented a major source of pollution due to re-suspension. The UV facility operated as expected, and the water at the outlet of the pilot facility was disinfected. Fecal coliform levels at the beach, however, still exceeded MOE guidelines for swimming and bathing use of water. This was explained by the re-suspension of contaminated sediments at the beach by bathers and groundwater springs. Testing of the sediments indicated fecal coliform counts of up to 200,000 per 100 g of sediment. Local seagulls were cited as a second major source of contamination.

BMP Guidelines and Criteria

In Canada, the recent focus has been on design criteria and guidelines for BMPs. Several U.S. agencies have produced design manuals and guidelines for BMPs (Schueler, Metro. Washington Council of Governments, 1987, U.S. Environmental Protection Agency, 1986, Minnesota Pollution Control Division, 1989, Maryland Water Resources Administration, 1986). While these manuals are extremely useful, extrapolation of their use to Canadian conditions has been questioned due to regional differences in climate and topography

(Comeau and Wisner, 1989). Some of these manuals provide sizing rules for different BMPs based on local average rainfall conditions, drainage area, and level of imperviousness (Schueler, 1987), while others are more regionally based on variable rainfall/runoff rates, volumes, durations, and intensities (U.S.E.P.A., 1986). Comeau and Wisner (1989) showed that a comparison of various U.S. agency sizing rules produced different design volumes even within the same jurisdictional area.

The Draft "Interim Stormwater Quality Control Guidelines for New Development" (M.O.E./M.N.R., 1989), tend towards the sizing rule approach, providing guidelines for storage volume based on type of receiving water and percent imperviousness. Certain compromises are made using a sizing rule criteria. On the one hand, it does not account for site specific problems. For example, in the Lake Simcoe region, phosphorus loadings are of concern. The draft guidelines are based on suspended solids removal only, and are not strictly applicable for phosphorus removal. Some shallow marshland or wetland plants would be required in a storage pond to provide nutrient removal. These requirements would not be addressed by the current guidelines. On the other hand, the sizing rule is simple and hence, easier to implement. Accordingly, the use of suspended solids is a natural choice for a "one stop" guideline since other pollutants, such as trace metals and hydrocarbons, have an affinity for sediment and tend to settle out with the sediment.

Randall (1982) has done research on total suspended solids concentration and found that higher suspended solids removal was associated with greater pollutant removal in general. The research indicated, however, that some pollutants, such as nutrients, were not related to the total suspended solids concentration. Randall also concluded that wet ponds were considerably better for nutrient removal than dry ponds, but no better for suspended solids removal.

Weatherbe, Marsalek and Zukovs (1982) analysed bench and pilot scale runoff treatability studies conducted over two monitoring seasons in a primarily residential catchment in Metropolitan Toronto. The study evaluated the effectiveness of plain sedimentation, chemically assisted coagulation/ sedimentation, and disinfection. No relationship was established between settling time and pollutant removal. They concluded that natural settling did not reduce bacteria levels. Therefore, research indicates that a blanket criteria based on suspended solids removal is inadequate for objectives concerning nutrient removal or bacteria control.

Comeau and Wisner (1989) argues against blanket type criteria stating that the optimum level of water quality control varies with specific watershed characteristics. They supported their argument by demonstrating that urban runoff had negligible impacts on receiving water quality in a predominantly agricultural watershed. This argument was supported by the findings of the Rouge River Study (Marshall Macklin Monaghan, 1988). In a similar vein, research on hydrocarbon pollution (Stenstrom et al,1984) indicated that the control of only 10 % of a watershed (commercial and parking lot areas) would potentially reduce 50 % of the watershed hydrocarbon loading. This research indicates that BMP controls on specific

areas may be more efficient than blanket watershed controls. The same relationship regarding water quantity and watershed controls was determined in Rouge River Study (Marshall Macklin Monaghan, 1988) which reinforces the need for Master Drainage planning.

Canadian Surveys

Research on BMPs in Canada has primarily focused on wet and dry quality ponds. Surveys regarding common design practices, public acceptance, and municipality acceptance of BMPs have been performed by various authors (Weatherbe et al., 1982, Michaels et al., 1985, Korsiak et al., 1986, Baxter et al., 1985).

A survey of 84 Canadian municipalities was performed in 1984-85 concerning storm water ponds (Michaels et al., 1985). Flood control, followed by water quality was most frequently cited as a reason for building a storm water pond. Guelph was the only city to use detention ponds for groundwater recharge. Extensive monitoring programs were noted in Winnipeg, Regina, Saskatoon, Calgary, Edmonton, Nepean, and Mississauga. Winter monitoring was not conducted. Mean annual maintenance costs for wet ponds ranged from $1500 to $2000 per hectare of pond (1971 $).

Monitoring, and a public survey were conducted on two urban lakes in Mississauga (Lakes Aquitaine and Wabukayne). These lakes were designed primarily for flood control and aesthetics, with water quality control being a secondary purpose. The Lake Aquitaine and Lake Wabukayne studies are discussed in detail in Section 2.3 and Appendix C.

Korsiak et al. (1986) surveyed 110 Ontario municipalities to determine the status of storm water management and the problems with its implementation. They contended that the Planning Act (1983) has given local municipalities the main responsibility for storm water management measures. Forty- four of the 71 municipalities who responded to the survey indicated that they had a storm water management program. Flooding problems, followed by environmental problems and Conservation Authority requirements, were the major factors motivating the implementation of a SWM policy. The two major problems encountered by municipalities in preparing Master Drainage Plans were lack of funding and low municipality priority. Impediments to the implementation of SWM noted by the municipalities were lack of municipal funds, lack of staff expertise, and lack of Provincial policy. A major problem encountered in the implementation of SWM was the lack of developer understanding. The majority of municipalities favoured greater provincial involvement. Possible areas of involvement were noted as subsidization of MDPs, training and education programs, and legislation concerning SWM.

Jurisdictional Responsibilities

Korsiak's municipal survey indicated that funding was an impediment to the implementation of stormwater management programs. The formation of a storm water utility is one method of circumventing funding problems regarding storm water management operations and maintenance tasks (Science Applications Int. Corp., 1987). The utility could be under the jurisdiction of a municipal authority (local or regional) and would be funded by development charges based on land owners' contributions to stormwater flows. The American Public Works Association (APWA, 1981) views user charges and the utility concept as "the most dependable and equitable approaches available to local government for financing SWM". Stormwater utilities have been implemented in several U.S. cities including Cincinnati, Ohio, and Denver Colorado (Roesner and Schogren, 1990). The stormwater utility in Denver has been in operation since 1980.

The use of taxes is another source of revenue for stormwater maintenance funding. Taxes are not recommended, however, since the use of tax money is vulnerable to changing priorities and deferred maintenance.

An interjurisdictional approach to storm water quality is used in Northern Virginia (Hartigan, 1986). An agency, which is composed of representatives from local municipalities, the Regional Planning Commission, the County water authority, and local soil and water conservation districts, is responsible for the implementation of non- point source pollution management programs. This paper stressed the desirability of consistent, area wide policies regarding storm water quality implementation.

BMPs and Landscaping

Landscape elements such as vegetation and grading are tools which are employed to enhance the effectiveness, aesthetics and level of acceptance of B.M.P. technologies. Terrestrial and aquatic vegetation are extremely effective in removing soluble pollutants from runoff. Vegetation is critical in the maintenance of water temperature and is an effective tool in decreasing velocity, controlling erosion and filtering out suspended solids. Combinations of engineering and landscape systems create the most effective pollutant removal systems.

The selection of BMPs and their ultimate effectiveness is governed by the site in which the system is to function. The integration of existing site features into the proposed development plan and the proposed BMP system has been proven to have a positive effect on the quality of runoff. Existing stands of trees can decrease the net amount of runoff from a site through interception. Existing vegetation in combination with forest floor litter absorb and trap significant amounts of rainfall. Existing stream course plantings of trees, shrubs and ground covers can be as effective as gabion and rip rap in controlling the erosion of watercourses while aiding in the maintenance of water temperature. Prior to the

proposal of any BMP within a site, a detailed inventory and assessment of existing site features which are already functioning as water quality improvement systems must be performed and existing site features retained and integrated into the proposed plan.

The selection of a BMP or system of BMPs must be coordinated with the proposed land use and site plan. Different land uses create opportunities for the successful integration of BMPs into the site plan to enhance effectiveness, aesthetics, ease of maintenance and social acceptance. Most BMP types can be integrated into the landscape of a development to achieve a net benefit if a coordinated, multidisciplinary approach to design is employed.

The importance of landscape elements in any BMP lies in the establishment of natural processes to remove or convert pollutants and the establishment of habitats for terrestrial and aquatic communities. The innovative use of landscape materials permits the successful integration of a BMP into a development plan while minimizing or negating the visual and physical impact of the facility. A sensitive landscape approach addresses not only the functional aspects of a BMP but also exploits the aesthetic and recreation opportunities afforded by the facility.

Summary of BMP Technologies, Effectiveness and Integration into Development

Conservation of Existing Site Features (i.e., Woodlots and/or Supplementary Mass Planting)

- Effective interception of precipitation and runoff.
- Effective absorption, detention and infiltration of runoff.
- Maintenance of water temperature (canopy)

Filter Strips

- Effective in filtering out suspended solids.
- Effective in intercepting precipitation.
- Encourages a degree of infiltration depending on soil type.
- Requires maintenance of spreader to ensure proper performance.
- Creates habitat for wildlife (wooded filter strip) or passive recreation opportunities (grassland).
- Not effective in freeze/thaw conditions.
- Minimal nuisance problems.
- High potential for integration into most developments as buffer, open space, wooded edge, lawn or yard.

Grassed Swales

- Moderately effective in filtering out suspended solids when properly maintained.
- Some degree of infiltration where soil conditions permit.
- High level of maintenance required to ensure proper function.
- Low cost to implement.

Vegetative Buffers

- Effective in filtering out sediments.
- Somewhat effective in controlling velocity and erosion.
- Effective in maintaining water temperature.
- Somewhat effective in the uptake of pollutants.
- Effectiveness varies with climatological changes.
- Minimal maintenance requirement.
- Minimal nuisance problems.
- Excellent potential for integration into most site plans - compatible with most land uses as:
- parks and open space
- buffer plantings
- trail systems/recreational uses
- High social acceptance.
- Effective in habitat creation.

Artificial Wetlands

- Effective in settlement of suspended solids.
- Very effective in the removal of soluble pollutants.
- Somewhat effective in maintaining water temperature.
- Very effective in the uptake of pollutants.
- Effectiveness varies with climatological changes.
- Minimal maintenance requirement.
- Some nuisance problems.
- Good potential for integration into open space systems for recreational and educational interest.
- Adaptable to most land uses and site plan configuration.
- Ineffective during times of frost and snow cover.

Combinations of vegetative BMPs utilized to treat runoff in a system represent an effective method of pre-treating runoff upstream of ponds and infiltration trenches. Vegetative BMPs are relatively adaptable to specific site conditions and site plan configurations. This flexibility makes them more suitable for use on smaller sites than most other BMPs. Vegetative BMPs can also be used as components of ponds and basins to add to their

effectiveness.

Landscape Elements Within Other BMPs

BMPs such as wet ponds, infiltration basins and extended dry detention ponds have a major impact on their surroundings not only from a functional viewpoint but also in spatial, environmental and visual terms. The detailed design of a BMP must address all of these terms of reference to ensure that the function of improving the quality of storm water is achieved with a sensitivity to the needs of the environment and the community. Many of the administration, maintenance and nuisance problems related to pond BMPs can be eliminated through effective detailed design that addresses not only function but recognizes aesthetic, circulation, land use, recreation and environmental opportunities created by the BMP. Landscape elements used creatively serve to make BMPs more acceptable and sustainable.

Extended Dry Detention Ponds

- Artificial wetlands in the bottom of an extended detention pond and planting of sideslope areas increases the efficiency of removal of soluble pollutants.
- Use of planting and grading to minimize maintenance and nuisance problems as well as to restrict access (eliminates the need for fencing and spraying of pesticides and herbicides)
- Natural plantings within and around BMPs aid in the establishment of habitats for wildlife.
- Creative grading minimizes maintenance and safety problems and creates opportunities for recreation while blending the facility into the topography of the site.
- The use of natural materials in the construction of risers, outfalls and spillways helps to integrate the facility into its surroundings and make it appear less engineered and more acceptable to neighbouring residents.

Wet Ponds

- Varying the grade and treatment of the shoreline as well as articulating the alignment of the shoreline creates opportunities for the establishment of a marshland fringe to support emergent aquatic plants.
- Use of riverstone and beach pebbles creates habitats for waterfowl nesting while aiding in erosion control.
- Undulating the topography of the floor of the basin and varying the depths of water throughout the pond creates habitats that will support a variety of aquatic plant life improving the performance of the pond. Localized deep pockets aid in mitigating water temperature fluctuations.
- Use of natural materials such as riverstone and rock to construct or conceal structures and control erosion helps to integrate the facility into natural,

recreational and open space systems as an amenity.

- Artificial floating islands fabricated out of metal or wood and anchored in larger ponds provide a floating habitat for aquatic plants and water fowl. The islands are unique in that their elevation remains constant even in times of severe drawdown, creating a stable habitat for aquatic plants located on the island. Islands provide habitat for waterfowl and shelter for fish as well as aiding in the control of fluctuations in water temperature and mitigation of erosion caused by wave and wind action. Aquatic plant communities established on floating islands increase the efficiency of removal of soluble pollutants. Floating islands require periodical maintenance and have a limited life span.

Effects of Ontario Climatic Conditions

The performance of vegetative BMPs is diminished during times of dormancy and is seriously impaired as a result of frost and snow cover. Vegetative BMPs may actually become a short term source of pollution during the autumn season due to leaf litter and dieback of ground cover. Fortunately this situation occurs at the time of dormancy for most aquatic biota and when a nutrient bloom has the least impact. The superior performance of vegetative BMPs in reducing the quantity of pollutants that remain untreated in BMPs which rely on settlement as the primary removal process overrides this short term liability. For this reason the inclusion of vegetative BMPs within storm water quality systems is essential to the removal of soluble pollutants. In healthy, stable and structurally diverse streams, leaf litter can be a primary food source for the aquatic community (i.e. aquatic bugs).

2.2 Literature Reference Database

A database of references concerning BMPs has been compiled using DbaseIII+. The database includes references from the Ministry of Environment, the Canadian water resources database (AQUAREF), the American National Technical Information Service (NTIS) database, and affiliated contacts. References from papers acquired in the literature review were also entered into the database. A total of 607 references were compiled in the database. A breakdown of the distribution of papers in the database based on specific areas of interest (Landscaping, Planning, Fisheries, Design, etc.) is presented in Figure 2.1.

2.3 Municipal Survey

Fifty six municipalities were asked to complete a questionnaire (Appendix E) concerning water quality facilities. These municipalities were chosen based on a minimum population criteria of 30,000. Twenty nine of the 56 municipalities which were contacted responded, representing a 52 % return rate.

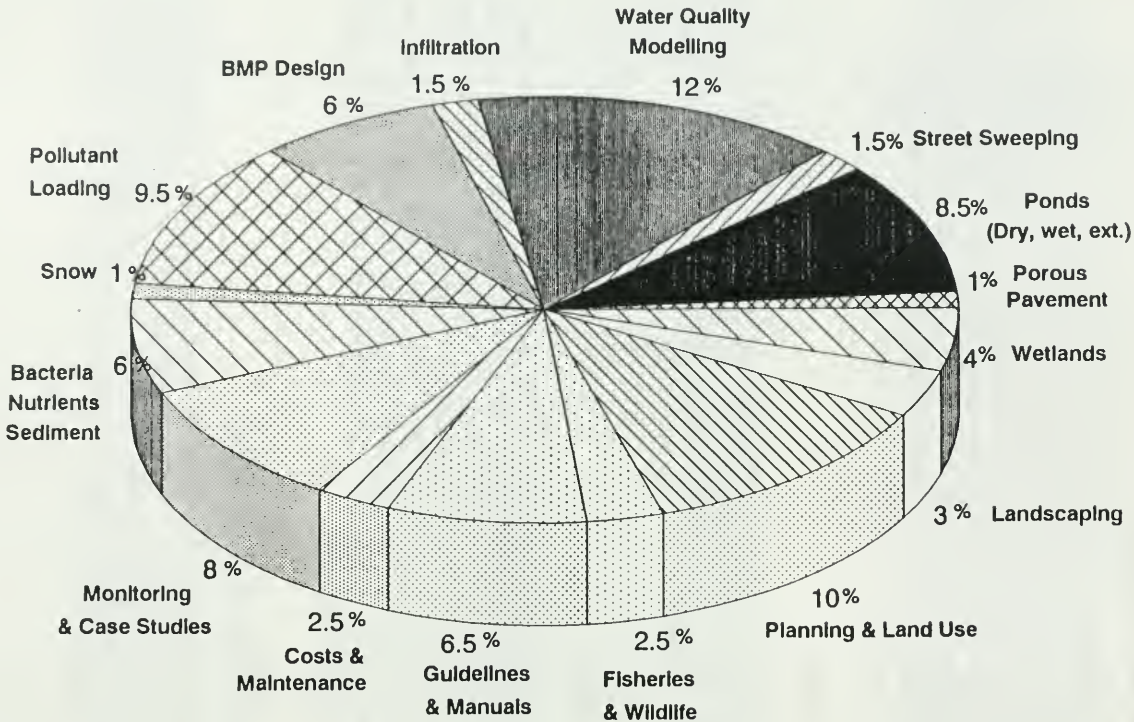
2.3.1 Existing BMPs

Figure 2.2 indicates that only 9 of the 29 municipalities indicated that there were water quality facilities located in their jurisdiction. The most prevalent water quality facility noted by the nine municipalities was wet ponds, followed by oil/grit separators and underground tanks as shown in Figure 2.3. The municipalities which responded indicated that there were only 3 infiltration facilities in operation province wide. Although these numbers are not exact, since 50% of the municipalities did not respond to the survey, the survey results indicate a greater use of wet ponds and underground tanks for water quality control as opposed to infiltration techniques.

2.3.2 Existing BMP Design Concerns/Criteria

Figure 2.4 indicates the range of criteria used in the design of existing water quality facilities in Ontario. A common pollutant criteria was sediment. It is interesting to note that the general concerns, and aesthetic concerns, were two of the most highly rated reasons for implementing the water quality features. The bacteria concerns were raised by the municipalities of Ottawa and Nepean.

Figure 2.1. Literature Database Contents Breakdown



(% of Papers Pertaining to)
(Total Number of Papers = 662)

2.3.3 Existing BMP Monitoring

There is very little monitoring data available on BMP effectiveness as indicated by Figure 2.5. The survey results were supplemented with other known monitored BMPs. There are six known municipalities where monitoring has been done :

- Ottawa - RMOC monitored data
- Nepean - RMOC monitored data
- Mississauga - Lake Aquitaine and Lake Wabukayne
- Owen Sound - Landfill Pond - monitored only effluent
- Richmond Hill - Mill Pond
- Brampton - Heart Lake Infiltration Pipe

2.3.4 Retrofits for Existing Quantity Detention Ponds

The survey indicated that there is only one proposed retrofit out of 112 existing water quantity detention ponds. This indicates that the issue of retrofitting ponds for quality enhancement is not a high priority mandate at the municipalities which responded to the survey.

2.3.5 Municipality Concerns with BMPs

The two major concerns with water quality facilities are the additional maintenance costs and perceived or expected aesthetic problems with the facilities. This is shown in Figure 2.6. This figure also indicates that safety and liability concerns are also prevalent amongst the responding municipalities.

The effectiveness of the BMP, both in pollutant removal, and remedial effect in the receiving waters, ranked as the fourth highest concern noted by the municipalities. This clearly demonstrates the bias of the municipality towards concerns which directly impact the municipality such as additional maintenance costs, potential lawsuits, and negative feedback from local residents.

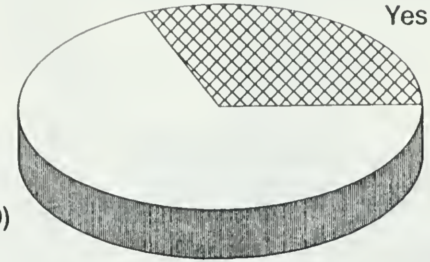


Figure 2.2 Number of Municipalities Using BMPs in Ontario

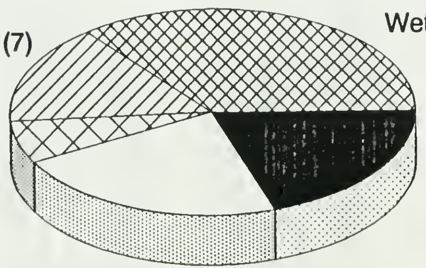


Figure 2.3 Existing BMP Types in Ontario

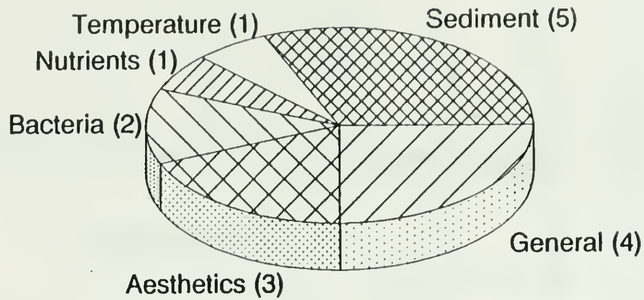


Figure 2.4 BMP Design Criteria Parameters

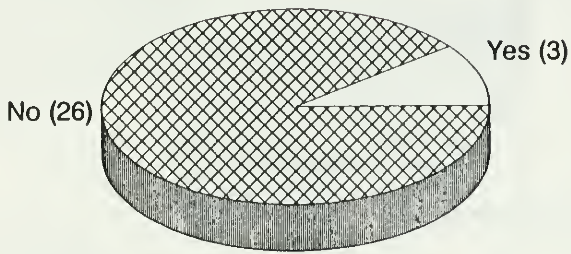


Figure 2.5 Existing Municipalities with BMP Monitoring Data

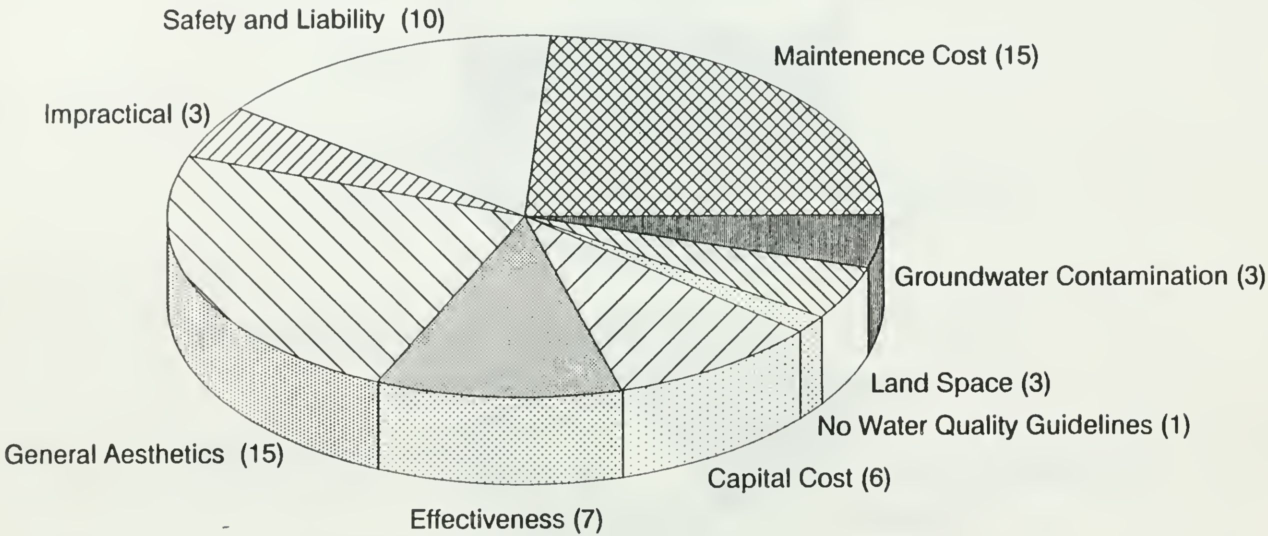


Figure 2.6 Municipality Concerns Associated With BMPs

2.4 Existing Monitored Data

The majority of existing monitoring data is discussed in detail in Appendix C. Other monitored data such as the sediment quality from Lake Aquitaine and water quality from Mill Pond is also included in Appendix C.

A general summary of the monitored data is presented in Table 2.1.

All of the monitored water quality data which was collected pertained to retention ponds. The use of surface ponds for quality control is understandable since ponds have been used for quantity control for the past 20 years.

Average concentration percentage removal rates (except for the Kennedy-Burnett Pond) are presented in Table 2.1.

Table 2.1 Average Concentration Removal Rates For Existing Monitored Retention Ponds in Ontario

Retention Pond	SS	P	N	BOD	Zn	Pb	Fecal
Uplands	79	45					93
Borden Farm	59	48					69
East Barrhaven	52	47					56
Merivale	83	46					87
Hunt Club Ridge	90	63					
Kennedy Burnett (batch) **	98	79	54	36	21	39	99
Kennedy Burnett (cont.) **	93	86	57	57			85
Lake Aquitaine	65	77	47				
Lake Wabukayne	0	25	0				
Mill Pond *	54	79					

Results are averages for all monitored storms
* Results are for the combination of wet pond and natural wetland
** Mass loading results

The use of the monitored data presented in Table 2.1 for estimating the performance of retention ponds is limited by the sampling technique used. The general procedure for sampling is to take grab samples at all monitoring locations at the same time. This type of monitoring is incomplete since flow quantity is not monitored and mass loading cannot be assessed. The required monitoring to accurately determine the effectiveness would involve periodic monitoring of both water quality and quantity. This type of monitoring is both expensive and time consuming. Since monitoring of this type is not required as part of the approvals process, it is generally not done. Even when extensive monitoring of both water quantity and quality is done, the resulting data requires careful screening since the majority of data is inaccurate due to operational problems and equipment failure or improper calibration.

In the Regional Municipality of Ottawa-Carleton some mass loading data which was useful was recorded for the Kennedy-Burnett pond. Other flow quantity data was recorded for certain ponds but was either inaccurate (inflow versus outflow volumes were wrong) or not performed at both the inlet and outlet of the pond. Operational problems compounded the interpretation of monitoring results at a number of Ottawa-Carleton ponds. These operational problems are described in more detail in Appendix C.

Table 2.1 indicates that the average removal rates for suspended solids varied between the ponds. The individual pond monitoring (presented in Appendix C) indicates that the removal rates also varied from storm to storm. This is expected since all of the ponds except for the Barrhaven Pond were designed on a one storm basis (not all ponds were based on the same storm). As discussed in Appendix C, pollutant removal effectiveness by BMPs will be affected by storm characteristics.

Table 2.1 shows that Lake Wabukayne provides negligible pollutant removal whereas a nearby pond, Lake Aquitaine, provides good pollutant removal. The lack of pollution control at Lake Wabukayne is a result of the pond being undersized for the area which drains into it. The drainage area at Lake Wabukayne is 4 times that of Lake Aquitaine, yet Lake Wabukayne has only half the surface area of Lake Aquitaine and one sixth the storage volume.

There is a need to clarify the effectiveness of wet ponds in reducing bacteria counts. Although the figures in Table 2.1 indicate that a high removal percentage of bacteria can be obtained with the use of wet ponds, the effluent still exceed M.O.E. guidelines for swimming and bathing use of water. Only 2 of the batch events at the Kennedy-Burnett pond met the fecal coliform criteria of 100 counts/100 ml, and all had a fecal coliform to fecal streptococci ratio greater than 4 (a ratio greater than 4 indicates that the bacteria is human in origin). This suggests that the control of bacteria requires a higher level of treatment than retention alone to satisfy the MOE bathing criteria.

Table 2.1 is only indicative of pollutant removal under summer conditions. Monitoring of

these BMPs has not been carried out during freeze/thaw conditions.

Even with the limitations of the monitoring techniques and the failure of wet ponds to meet M.O.E. criteria for body contact recreation, Table 2.1 indicates that wet ponds are generally beneficial in pollutant removal during summer conditions. The effectiveness of the BMPs are dependent on both storm characteristics and design parameters (retention time, surface area, depth, etc.).

The operational problems encountered in the Rideau River BMPs, and the resulting problems in monitoring interpretation emphasizes the need to properly operate BMPs which are being monitored. Conducting measurements on BMPs which are not properly operated is a counter-productive exercise.

2.5 BMP Workshop

A workshop was held on April 18th and 19th, 1990 to discuss the following topics concerning BMPs :

- Overview of Current BMP Technology
- Overview of BMP Effectiveness
- Canadian Concerns/Differences
- Design Considerations
- Planning/Approval/Monitoring Process
- Environmental Issues
- Operations/Maintenance/Public Concerns
- Research Needs/Pilot Projects

Approximately 30 people attended the workshop representing all aspects of BMP planning, design and review.

Many of the sections were influenced by the workshop. The BMP research needs are directly related to information resulting from the workshop. A complete summary of the entire workshop is presented in Appendix D.

2.6 BMP Technical Conclusions

Several conclusions can be made from the literature review, municipal survey, existing monitoring, UDI concerns, and BMP workshop.

a) Groundwater Contamination

The municipal survey indicates that groundwater contamination is a prevalent concern. The issue of groundwater contamination is primarily related to drinking water due to the mobility of chlorides and nitrates and immobility of metals.

The heavy winter use of road salt in Canada indicates that drinking water contamination would be a more prevalent concern in Canada than the United States. The lack of groundwater quality data in Canada indicates the need for pilot infiltration quality/quantity monitoring projects.

b) Sediment Toxicity and Accumulation

The conclusion which can be drawn from the literature on sediment toxicity is that the sediment will become contaminated, the level of which will be site specific depending on the drainage area, land use, and BMP effectiveness. The sediment will likely have limited disposal options even if it can be classified as clean fill. This does not imply that sediment cannot be disposed of on-site, but does suggest that there will be restrictions to on-site disposals. The accumulated sediment must be tested to determine the disposal options.

It is recommended that research be carried out on biological interaction with contaminated sediments. Specifically, studies need to be performed to determine the uptake of contaminated sediments in biota, and the implications for disposal practices of sediment removed during maintenance.

The debate on sediment toxicity is, in essence, academic. Higher pollutant levels would be distributed into rivers and lakes if BMPs were not used to trap the sediment. The entrapment of polluted sediment provides confirmation that the BMP is working (protecting the downstream watercourse), and as such, justifies its implementation. BMPs do not produce polluted sediment; urban development and agriculture do.

c) Seasonality of BMPs

There is a definite seasonality to runoff in Canada which must be taken into account when designing a BMP solution for a particular site, tributary, or watershed.

A higher percentage of the annual runoff occurs in the spring (Section 5) than in the summer, fall, or winter. Spring runoff occurs over several days whereas summer runoff is characterized by many short duration events. This change in hydrologic conditions with season must be viewed in conjunction with seasonality changes in water quality concerns to effectively select and design BMP solutions. For example, if the downstream water quality objective was body contact recreation, then the use of summer hydrologic conditions would be applicable. However, if the concern was basin sediment export, the use of spring hydrologic conditions would be warranted.

The effectiveness of BMPs, especially infiltration techniques, is questionable during the spring. As such, pilot monitoring studies are required to determine the applicability of BMPs during the hydrologic conditions of the different seasons.

The use of road salt during the winter produces chlorides which are highly soluble and a major threat to groundwater quality. It is not possible to remove chlorides with current BMP technology. As such, source controls, such as the elimination of road salt use in the case of chlorides, must be used to prevent groundwater contamination.

d) Design Considerations

a) The level of protection provided to a watercourse should be dictated by downstream water uses
b) Other design factors for BMPs should include
   - spill control
   - safety
   - aesthetics
   - multiple use
   - maintenance
   - cost
   - vegetation and shading requirements
   - development intensity (land use)
   - sediment and erosion control measures
   - quantity control
c) A continuous analysis approach is recommended to determine regional guidelines for the design of BMPs.
d) Soft BMP approaches such as lower density development, and additional green spaces, should be used in conjunction with structural BMPs.

e) An immediate downstream water use of body contact recreation may require a higher level of treatment than that provided by wet ponds due to the high fecal coliform loading associated with stormwater. It should be noted, however, that the stringency of the effluent criteria depends on the distance of the development from the water contact area, and the bacterial die-off rate in the receiving waters. Wet ponds can provide significant benefits with respect to bacterial control, and therefore, may be used in areas where the bacteria die off to acceptable levels upstream of the body contact area.

e) <u>BMP Planning and Approvals</u>

More provincial direction is required for Watershed Planning to effectively manage and protect watershed resources. Provincial direction could be made through policy statements issued under the Planning Act, and would require the identification of funding and implementation responsibilities, and allocation of provincial resources necessary for implementation.

f) <u>Environmental Issues</u>

a) Watershed planning should define water quality objectives in different parts of the watershed and should set land use planning criteria based on these objectives. This would ensure the goal of "environmentally sustainable economic development".

b) Watershed planning must integrate the water quality objectives with water quantity objectives if healthy aquatic ecosystems are to be maintained or promoted.

c) Urban development will result in water quality degradation, and BMPs cannot completely mitigate this degradation. While it is recognized that some habitat degradation may be unavoidable, the implementation of BMP techniques provide an opportunity to enhance previously degraded systems such that there is a net improvement in water quality through urbanization.

d) Historically, stormwater has been regarded as a nuisance. A change in attitude is required such that stormwater is regarded as a resource.

g) BMP Operation and Maintenance

a) The developer should be initially responsible for the operation and maintenance of BMP facilities for a minimum period of 2 years.

b) Long term maintenance of BMP facilities should be the responsibility of the municipality. Municipalities have the resources to provide maintenance, and are accountable to the public.

c) Funding for BMP operation and maintenance needs to be provided by one of three ways :

- taxes
- developer levies
- public utility

Of these three, taxes are the least preferred, since tax monies can easily be reallocated based on current municipality priorities with maintenance being deferred. Recent legislation on developer levies needs to be reviewed, and revised, to make developer levies applicable to BMPs in Ontario. Public Stormwater Utilities appear to be the most feasible solution for stormwater quality BMP maintenance. A stormwater utility would be under the jurisdiction of the local municipality.

h) Municipal Concerns

The major concerns of municipalities with respect to BMPs are related to maintenance, aesthetics, and safety/liability. This is understandable since the municipalities have a limited budget, must deal with the public on a day to day basis, and are subject to civil lawsuits arising from safety problems with municipal infrastructure.

The perception of water quality works being the responsibility of the municipality also conflicts with the traditional views held by some municipalities. Historically, water quality issues have been the responsibility of the regional municipality and not the local municipality.

There needs to be an additional source of BMP funding. BMPs require frequent maintenance to ensure efficient operation. The cost of maintenance is BMP specific, but it suffices to say that the cost of maintenance is proportional to the effectiveness of the BMP.

The issues of aesthetics and safety/liability are perceived problems and should be dealt with during the design of the BMP. BMP implementation in the U.S. (Maryland) has received favourable feedback from local residents even though BMPs have been located within subdivisions. Liability resulting from BMP safety (children near open water) has not been an issue to date in Maryland even though most of the wet ponds are not fenced. Generally,

property values in the vicinity of BMPs are higher than property values in areas without BMPs.

Safety and aesthetics are linked by BMP design. In the case of a wet pond, fencing may be perceived to improve safety but make the pond aesthetically displeasing. Proper landscaping around the pond, such as benching near the water surface, and the planting of vegetation to stabilize slopes, enhances the aesthetics of a BMP design while incorporating safety features. Shoreline vegetation provides additional benefits such as additional pollutant removal, and the creation of habitat and food sources for aquatic and terrestrial wildlife.

Maintenance and nuisance concerns related to pond and marsh BMPs can be eliminated or mitigated through effective landscape design. Landscape treatment of BMPs assists in the integration of BMPs into developments, in achieving public acceptance of BMPs, and increasing the marketability of a project and the market value of existing developments. Vegetative BMPs represent a good return on investment in terms of capital cost and performance.

A multidisciplinary approach to BMP design is critical in ensuring that BMPs not only function with efficiency, but are also integrated into the proposed development capitalizing on the opportunities for aesthetic enhancement, safety, and recreation.

Public surveys at Lake Wabukayne and Lake Aquitaine attest to the amenity features which can be provided by a BMP (Baxter et al., 1985). Therefore, it is anticipated that BMPs will be favourably received by the public if designed properly.

i) <u>Private Sector Concerns</u>

The main concern of the private sector is that the approval time for developments will become protracted since there are no clear guidelines concerning stormwater quality treatment. The lack of guidelines is compounded by the lack of BMP familiarity on the part of both design engineers and reviewing agencies. Further concerns arise with the conflicting objectives of different agencies and the responsibility for BMP maintenance.

These concerns are well-founded and expected during a period where water quality design practices are new and evolving.

The BMP research which has been performed indicates that an improvement in downstream water quality will occur since pollutants are removed by the BMPs. This limited technical justification for BMPs is sufficient to proceed with their implementation. The implementation of BMPs is required to determine the applicability of BMPs during freeze/thaw conditions and the effect of BMPs on receiving waters.

Before BMPs can be implemented, however, guidelines must be set for the planning, design,

approval, and monitoring of BMPs. These guidelines must be in place before the effectiveness of BMPs in Ontario can be definitively ascertained, since they will affect the choice of BMP, BMP design parameters, and BMP implementation and maintenance.

j) <u>Research Needs and Pilot Studies</u>

a) BMP research under winter/snowmelt conditions (especially infiltration techniques and retention (wet) ponds)
b) Research on dissolved versus suspended pollutants, and the re-suspension of settled solids by wave action, swimmers, and subsequent storm events.
c) Receiving water quality improvements resulting from BMP implementation
d) Mass loading pollutant monitoring studies
e) Research on standard monitoring methods for BMPs
f) Bio-accumulation of urban stormwater pollutants
g) BMP design standards in the Canadian climate
h) Time of concentration on a watershed basis for the first flush of urban pollutants (where relevant)

The provincial government (Ministry of Environment and Ministry of Natural Resources) are the appropriate agencies to provide funding for this research. The implementation of this research should be delegated to the local municipalities and conservation authorities.

Routine monitoring of water quality parameters is recommended for all new BMP installations to determine the effectiveness of the facility. This monitoring should be funded by the developer since the facility would still be his/her responsibility at this time.

The monitoring data should be compiled on a province wide basis into a data management system which could be accessed by all planning/reviewing agencies. Information, in addition to the monitored data, which should be collected includes :

- BMP inventory
- Stream classifications
- Sampling methods
- Long term effects
- BMP maintenance
- Public acceptance (concerns)

3.0 THE PLANNING CONTEXT

3.1 The Overall Planning Approach

The overall planning process for urban development is well established, although the details of implementation often vary from municipality to municipality. Watershed planning is far less established as a practice. Over the last two decades, planning for flood control and hazard reduction have become common, but until recently little attention has been paid to water quality (except for point sources), aquatic resources, or other environmental resources. Efforts to address these issues have been improving but there is still a lack of consistent linkage between watershed planning and land use planning.

The requirement for BMP planning, and the selection and implementation of these controls is critical to the concept of environmentally sustainable development. In order to be fully effective, BMP selection must be incorporated into the municipal planning process at all levels. The relationships between drainage planning and urban planning are shown in Figure 3.1. BMPs should be addressed (at increasing levels of detail) in the formulation of the Watershed Plan, in the development of the Master Drainage Plan, and at the Stormwater Management Plan level. The Watershed Plan should be linked to the Official Plan; the Master Drainage Plan should be in place prior to Secondary Plan approval; and the Stormwater Management Plan should precede the approval of plans of subdivision.

Unfortunately, while most agencies agree with the process shown in the figure there are specific problems which often make adherence to the ideal untenable. In many cases, watershed planning issues are fed into the municipal planning process at too late a date, forcing a retrofit or remedial approach to water protection. A lack of policy and guidelines, limited technical expertise in a relatively new field, no clear jurisdictional authority, concerns about slowing up the municipal planning approval process, and the rapid pace of development, have all contributed to the problems in implementing water quality BMPs.

Many different agencies have recognized the problems which currently exist. Workshops, forums, and in-house discussions have been held at various levels. One such workshop was held by the Metro Toronto RAP. This workshop brought together municipal planners and lawyers, as well as agency staff from MOE, MNR, MMA and the conservation authority.

The result of the workshop was consensus that while some improvements might be possible in the municipal planning process, the main need was for the development of comprehensive resource management strategies for individual watersheds in order to feed information into the planning process.

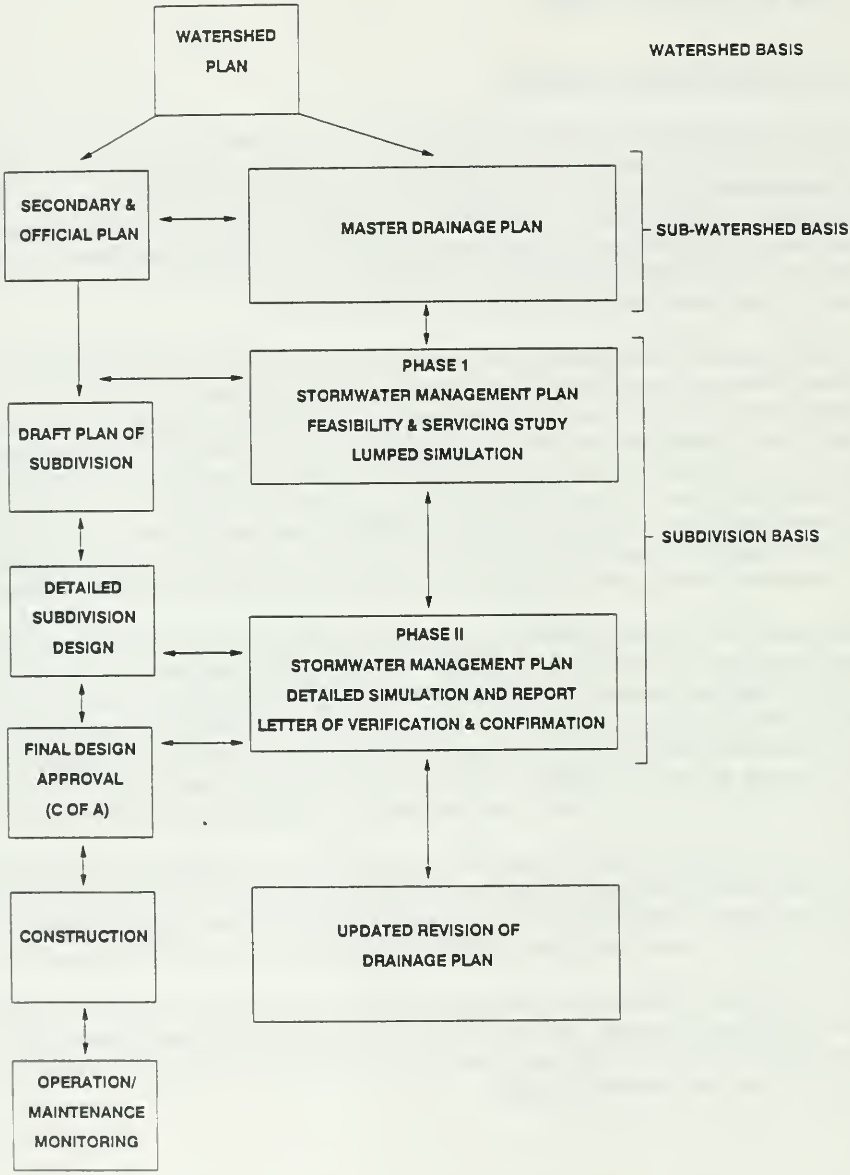


FIGURE 3.1 URBAN DRAINAGE AND LAND USE PLANNING FOR NEW DEVELOPMENT

A top-down initiative is required, with provincial agencies taking the lead in establishing the process by which these strategies are to be developed. The example of flood control may be cited as a similar process which works well. The success of this program is attributed to clear direction from the province in the form of policy statements and a clearly defined mandate to Conservation Authorities for implementation. Municipal authority under the planning act is an important delivery mechanism for the overall process.

A skeleton of what might be involved in a process for comprehensive resource management strategies is provided below for illustrative purposes only (Metro Toronto RAP Draft Discussion Paper on Remedial Options, 1990).

1. <u>Develop Provincial Direction for Completion of Comprehensive Resource Management Planning on a Watershed Basis.</u>

   The province should establish a strong basis for resource management planning using the watershed as the basic planning unit. This would require the development of provincial direction through policy statements or other mechanisms, identification of implementation and funding responsibilities, and allocation of the provincial resources necessary for implementation.

2. <u>Establish Guidelines for the Development of Resource Management Plans</u>

   The guidelines should specify the lead agency, other resource agency and municipal involvement and opportunities for involvement by public interest groups. It should indicate the issues to be addressed. Based on examples of recent work by MTRCA (eg. the Rouge Strategy, Oak Ridges Moraine interim planning guidelines) the following components could be included as elements of a resource management plan.

a) Water Management Component
- Water Quantity
- Water Quality
- Water Taking/Water Supply
- Fisheries
- Wetlands
- Aquatic Habitat

b) Terrestrial Management Component
- physical features
- major resources (wetlands, ANSIs, ESAs, Riparian Habitat Zones)
- open space linkages

Under each component of the Resource Management Plan it would be necessary to conduct inventories, assess potentials, develop targets and objectives for preservation, protection and enhancement, on a watershed basis. The guideline should identify the need to specify municipal policies on a subwatershed level so that a linkage can be made between the Resource Management Plan and individual Official Plans. Municipalities should be requested to reflect the direction provided by the watershed Resource Management Plan at the appropriate levels in their planning documents and process.

A key element of the Water Management Component is the development of Master Drainage Plans (MDPs). Guidelines currently exist for the development of MDPs but they are oriented primarily to quantity control of surface water resources. Recent MDP guidelines (Region of Waterloo, 1990) have been expanded to include consideration of water quality, groundwater, fisheries and wetland concerns. MDPs should be completed at a subwatershed level and should be completed prior to approval of municipal official or secondary plans. A corresponding level of plan should be prepared to address the Environmental Management Component. In the absence of policies on a subwatershed level, the requirements of the Resource Management Plans should be met at a local level as a part of site plan or subdivision approval.

3) <u>Establish Guidelines for Development of Detailed Management Plans</u>

The application of the watershed Resource Management Plan at a local level should involve stormwater management plans and resource conservation plans. These plans must be consistent with the watershed Resource Management Plan and must provide sufficient detail for use in the municipal subdivision and site plan approval processes. Of particular importance to this level of plan is the development of technical guidelines (by the province), such as the Interim Stormwater Quality Control Guidelines. Guidelines should specify numerical criteria, or the methods to be used in developing site-specific criteria. Technical guidelines could include recommended setbacks, riparian buffer distances, infiltration targets, temperature and water quality targets among others. Guidelines should also be available for enhancement opportunities, including plantings for stream shading and stream habitat improvement.

Development of a process for Comprehensive Resource Management Plans on a watershed basis would be the primary responsibility of those agencies with resource management mandates (the Conservation Authority, Ministry of Natural Resources and Ministry of the Environment). During the development of the actual plans it is important that there be both municipal and public involvement. The results of the plan development at all levels must feed into the municipal planning process to ensure that environmental issues receive attention at each phase of the municipal planning process.

3.2 BMP selection in Relation to Watershed and Urban Planning

Watershed planning and urban planning are necessary to successful BMP selection. The converse is equally true. Without assessment of BMP capabilities there can be no assurance that the planning goals established can be attained or sustained. Each of the major planning levels are discussed below, in relation to their interaction with BMP selection.

3.2.1 Watershed/Official Plan

The watershed/comprehensive resource management plan and the municipal official plans are the primary means of specifying the goals and uses to be made of the land and aquatic resources within a jurisdiction. This information should drive the BMP selection process. The identification of resources to be protected and uses to be maintained or restored will define the utility of different BMP options and will suggest combinations of BMPs for implementation. This is discussed in greater detail in the next chapter.

The watershed plan will also provide requirements on development and information on remedial initiatives which must be taken into account in subsequent BMP selection stages. These may include development restrictions to maintain riparian habitat, stream habitat enhancement projects, or revegetation of stream banks.

It is important that an initial assessment of BMP capabilities and limitations be undertaken at this level. BMPs have limitations, because of physical constraints and their efficiency in contaminant removal. Water quality goals and targets established in the watershed plan should be tested against BMP ability to achieve the desired results. In some cases it will not be possible to achieve all desired results through the use of structural or vegetative BMPs. In such cases decisions must be made regarding use and resource priorities, the acceptability of using house-keeping practices to address outstanding concerns, or the need to implement "soft" BMPs such as down-zoning. Failure to assess BMP capability at this stage may result in land use designations and densities becoming "locked in", resulting in an inability to meet desired goals without total curtailment of development at a later date.

3.2.2 Master Drainage Plan/Secondary Plan

This is the most critical level for ensuring an integrated approach to BMP selection. It is at this stage that the orientation of the overall BMP plan must be established. The BMP plan may range from emphasis on regional facilities to reliance on local systems. At either level, surface storage BMPs may be sited on-line or off-line. Each orientation has advantages and disadvantages, and the selection should be determined by use priorities and the physical constraints of the watershed.

In general, the fewer the number of storm sewer discharge points that exist on a watershed, the smaller the number of potential problems. This argues in many cases for efficient regional facilities. These facilities are typically preferred when issues such as flood control, erosion protection or contaminant export from the watershed are of greatest concern. Regional facilities are often not the preferred means of addressing in-stream concerns such as fishery or baseflow maintenance. Because of the characteristics of the BMPs available, selection of a wholly regional system will lead primarily to surface storage BMPs while selection of a locally oriented system will tend to place greater emphasis on infiltration BMPs. Vegetative BMPs can be utilized in either case, but are generally of a lower order of effectiveness.

Regional or local systems which employ surface storage may be created either on-line (on a flowing watercourse) or off-line. On-line systems tend to segment the watershed, acting as barriers to fish migration. While on-line BMPs will rarely be placed on main river channels, they will often be placed on tributaries or sub-tributaries. In doing so there is an implicit decision to accept a lesser water quality above the facility than below. On-line systems do have advantages however. They take advantage of natural topography and can usually be integrated into natural systems more easily. Because they are often on undevelopable or less developable land, there is a tendency to make greater use of the potential opportunities presented by the facility, rather than to minimize these because of their potential impact on the development. On-line facilities receive fresh water input continuously, usually reducing the potential for aesthetic impairment of the facility and enhancing its potential as an amenity for the development. The Ministry of Natural Resources rarely accepts on-line ponds since they are viewed as presenting barriers to fish migration, increasing water temperature, and altering habitat and channel morphology. In situations where on-line ponds would be acceptable there would likely be compensation required under the Federal Fisheries Act.

Inherent in the discussion of on-line versus off-line facilities is the need to clarify the definition of on-line versus off-line. In some circumstances the term on-line has been applied to end-of-pipe facilities because the upstream drainage area is greater than 125 ha. It is questionable whether a facility can be considered on-line if there is no open watercourse upstream of the facility.

Decisions regarding regional versus local controls and on-line versus off-line storage are most appropriately made at the master drainage plan/secondary plan level. At this stage the desired uses and resources to be protected should have been identified and these should drive the initial selection of candidate BMPs. Sufficient data will normally have been collected to allow BMP screening based on physical constraints and priorization based on anticipated development configuration. It may not be appropriate to select the specific local BMPs to be used at this stage but the required performance of the local BMP plan should be defined.

Typically the BMP selection process coupled with the master drainage plan will:

- specify the size, type, location and performance characteristics of regional BMP facilities
- identify the requirements for and performance characteristics of local BMP plans based on uses to be maintained. Specific design targets for infiltration, peak runoff, retention time, and temperature should be set.
- specify requirements such as bacteria control or oil/grit separators, based on the land use contemplated and the uses to be protected above any regional facilities
- identify specific local resources of regional significance to be protected (ANSIs, ESAs, etc.)
- confirm the capability of the BMP plan, coupled with other remedial initiatives, to meet the goals of the watershed plan with the selected combination of regional and local facilities.

3.2.3 Stormwater Management Plan

The final level of the BMP selection process should take place as part of the stormwater management plan stage. At this point the required performance characteristics of the local BMP plan should have been established and the physical feasibility confirmed for these criteria. Since the performance characteristics have been specified at the master drainage plan level, the approval agencies should not be concerned about the combination of BMPs selected, except insofar as responsibility for maintenance or replacement are concerned. The proponent should be free to choose those BMPs which best suit the development, while meeting the performance requirements. Selection of the elements of the BMP plan will be based on costs (capital and operating), the nature of the development, and opportunities provided.

The greatest opportunities for innovation will occur at this level in the BMP selection process. Approval agencies must seek to encourage innovation by judging the proposed BMP plan based on the performance characteristics for the entire site. For example, it may be appropriate to relax temperature requirements or minimum retention times for surface storage devices if significant areas are being controlled by infiltration devices. The net effect of this combination may be more desirable than could be accomplished by surface storage alone and this should be recognized. Failure to exercise reasonableness and practical judgement in this regard will discourage innovative design and lead to the loss of many opportunities. Agencies must be willing to alter criteria to suit specific circumstances.

3.3 Integration of BMP Selection into Existing Planning Processes

The BMP selection process fits well with the overall drainage planning process and should be incorporated into it, rather than setting up a separate review and approval process. Municipal involvement throughout is critical, and below the watershed plan level, the local municipality should assume the coordinating role. It is vital that the result of BMP planning be fed into the municipal planning process, both in an advisory fashion and as specific criteria which will govern development control. The following summarizes the preferred involvement by the primary agencies in the drainage planning process and indicates the information to be transferred into the municipal planning process.

Watershed Plan

Lead Agency:	Conservation Authority
Commenting Agencies:	MOE, MNR, all watershed municipalities, MTO
BMP Output:	Confirmation of the ability of "hard" BMPs to fully address watershed goals, issues and concerns or Identification of limitations on "hard" BMPs and recommendation for housekeeping practice requirements or "soft" BMPs such as down-zoning
Municipal Planning:	The requirement for BMP selection and implementation should be incorporated into the Official Plan or Secondary Plan, as appropriate to the municipality Amendments to Official Plans or Secondary Plans in instances where changes in land use designation or density are required.

Master Drainage Plan

Lead Agency:	Municipality *
Commenting Agencies:	MOE, MNR, Conservation Authority, MTO
BMP Output:	Regional BMP facilities; local BMP performance criteria; regional resources to be protected; special requirements (eg oil/grit separators for specified land use types).
Municipal Planning	Incorporate specifics of BMP plan (including target infiltration, runoff coefficients etc.) into Secondary Plan

* Lead Agency would be Conservation Authority or Regional Municipality if there was more than one municipality in the Master Drainage area.

Stormwater Management Plan

Lead Agency:	Municipality
Commenting Agencies:	MOE, MNR, Conservation Authority (specific approvals may be required by each of these depending on the BMP plan), MTO (if required)
BMP Output:	Preliminary BMP design; final design
Municipal Planning:	Acceptance of SWM should be contingent upon any required agency approvals

3.4 BMP Selection in the Short Term

The BMP selection process described on the next chapter may be followed in conjunction with the three-tier watershed planning/municipal planning process and this is the recommended procedure. The selection and implementation of BMPs is new however, and there are many instances where municipal planning approvals have proceeded past the stages corresponding to the watershed plan or even the master drainage plan. In such cases, the proposed process can be applied at the plan of subdivision or site plan level.

The process remains the same, but there will be a need for substantive consultation with MOE, MNR, the Conservation Authority and the municipality in order to establish the concerns, priorities, and uses to be protected (normally determined in the watershed plan). In the absence of a master drainage plan (with a BMP component) there are unlikely to be any approved regional facilities and so the requirements placed on the local BMP will be more stringent, because no control can be credited to regional facilities.

While the BMP selection process can be applied to the individual development level, it is likely that the results of the selection process at this level (without Master Drainage planning) will encourage its application at the master drainage plan level in future developments because:

- Regulatory agencies are likely to be uncertain as to the level of use potential for the receiver, in the absence of a watershed plan or master drainage plan. They will therefore tend to require stricter performance criteria (eg cold water rather than warm water fishery) in order not to limit future rehabilitation or stream enhancement options.

- Since the BMP selection process only allows the elimination of potential BMPs on the basis of physical infeasibility or redundancy in addressing use concerns, BMP plans for specific sites will typically need to be more comprehensive and will therefore be more expensive and more likely to encumber the development design.

- Local BMP plans are less likely to be able to fully address the concerns established by regulatory agencies and this is likely to result in approval delays or outright opposition during the planning approval process.

3.5 Applicability of BMP Selection Process

The same criteria and guidelines for BMP performance, based on receiving water quality objectives, that apply to new development cannot be applied to re-development or retrofit situations. Both re-development and retrofit situations require specific agency implemented programs which clearly set out the objectives and phasing of water quality enhancements.

However, once the phasing, water quality objectives and hence, performance criteria, have been identified, the local BMP selection process could be applied. It should be recognized that the BMP selection process, as it relates to the planning process, was developed for new development applications only.

The only recognized constraints on BMP selection for new development are due to physical capabilities of the site and water quality concerns/objectives. Land use considerations may be used to prioritize BMPs only. In a redevelopment situation, additional constraints

(because of the need to maintain existing infrastructure) may also be used to screen out BMPs. While in new development situations the BMP plan must address all use concerns in order to avoid consideration of only "vegetation" BMPs, in redevelopment this may not be feasible and the BMP plan should be judged on whether it meets the objectives set forth in the overall redevelopment quality plan. Objectives of such a plan may be as simple as requiring the redevelopment to provide distinct improvements over existing conditions.

Redevelopment and retrofit programs are not mandatory, and would be implemented based on a reviewing agency consensus of a need to improve downstream water quality and willingness to fund the program.

BMP selection in retrofit situations is similar to redevelopment except that there may be further restrictions, especially on vegetative BMPs, because of private ownership.

4.0 BMP SELECTION

4.1 Considerations in BMP Selection

A wide range of BMPs are available for possible use in stormwater quality management. Each BMP has advantages and disadvantages and the determination of which BMP (or combination of BMPs) is appropriate or "best" in a given situation can only be determined on a case-by-case basis. This is because the perceived disadvantages of any particular BMP in one situation may be irrelevant in another. In most cases, however, it appears that combinations of BMPs probably offer the most creative and effective solutions in terms of meeting flood and pollution control objectives while simultaneously achieving broader "ecological" objectives.

The state-of-the-art of different stormwater management BMPs is evolving, and a great deal of research and development into BMPs remains to be undertaken. Following the research, pilot scale studies will be needed. At present, caution must be exercised in attempts to extrapolate the knowledge gained in places such as Maryland to situations in Ontario. Some of the reasons for this are :

- There are four (4) levels of government involved in the planning and approval stages of storm water quality controls (Ministry of Natural Resources, Ministry of Environment, Conservation Authority, and Municipality).

- Certain municipal practices in Ontario differ from Maryland. It is customary for Ontario municipal engineers to require 1200 mm cover on all storm sewer pipes. This cover necessity often precludes the use of surface ponds within developments on the tablelands. Most Ontario ponds are located in the valleylands due to the requirement to meet grade on the pipe system.

- The funding of projects differs in Ontario from the States. There is less government funding of projects in Ontario than in Maryland. The political climate of Washington D.C. plays a large part in being able to obtain funding for non-point source pollution control studies. The funding of urban stormwater quality studies in Ontario comes from private developers in the development process.

- Ontario has a higher percentage of cold water streams. The protection of these streams requires mitigative measures in upstream areas. In this scenario, storm water quality controls would be required throughout a watershed.

- In Ontario the public expects to use some streams for body contact recreation (swimming). In Maryland the public accepts the loss of swimming privileges in their waterways. The control of bacteria (for body contact) requires a higher level of storm water quality control.

- Generally, higher density development occurs in Ontario than in Maryland. This implies that the U.S. pollutant loading rates, and hence sizing rules, for BMP design may not be transferable to Ontario.

- The sediment and erosion controls during construction are more stringent in Maryland than in Ontario. Unless similar controls are placed in Ontario, on-line storm water quality facilities will be subject to greater sediment loads in developing watersheds.

- In Maryland there is a distinct separation between storm water land use and park land dedication. In Ontario, storm water facilities tend to be placed in parkland areas, since the majority of facilities implemented to date have been dry quantity ponds. The effect of retrofitting dry ponds for wet quality ponds would preclude the use of the parkland for recreation.

- The climate of Ontario is different from Maryland. The majority of Ontario watersheds are subject to a heavy volume of runoff during the spring freshet. The utility of infiltration techniques during this period is questionable since the upper soil zone would be either frozen or saturated. Pond operation during ice conditions has not been well documented and gives further rise to questions concerning BMP effectiveness during periods of spring runoff.

Nevertheless, enough <u>is</u> known that as long as we are conservative in applying what has been learned elsewhere regarding the incorporation of BMPs into stormwater management systems in Ontario, we can proceed with their implementation. There is no need what-so-ever to defer implementation of BMPs until more information is available.

Regardless of the BMP or combination of BMPs selected, the following objectives should be kept in mind when conducting urban BMP planning, selection and design:

1) On a philosophical basis, recognize that approaches to stormwater management must embrace the concept of "environmentally sustainable economic development". The approaches used in the past which resulted in the "export" of one municipality's (pollution) problems downstream to the next, the incremental reductions in groundwater levels, and the destruction of natural ecosystems are no longer acceptable. Stormwater must be viewed as a resource to be managed rather than a waste to be disposed of.

2) Maximize, to the greatest possible extent, the utilization of non-structural stormwater management BMPs. For example, subdivisions should be designed to maximize use of the natural infiltration capacity of the soils. As well, simple approaches such as

maintenance of adequate buffer strips, or use of swales offer distinct "low-tech" advantages.

Supplementing these objectives, there must be recognition that BMPs are inherently designed to reduce contaminant impact on downstream areas, primarily through retention of contaminants locally. Many contaminants are persistent and management/disposal of accumulated contaminants must be addressed within the context of local versus downstream impacts.

4.2 Context for Selection

The uses made or desired for the receiving stream or body of water and the resources existing and in need of protection, both locally and downstream, are necessary to provide a context and starting point for BMP selection. Use of BMPs may be required because of basin export concerns, downstream/instream use or local concerns.

There is no blanket hierarchy or priority associated with these different concerns, except as defined by the watershed planning process. Each set of concerns however, will tend to define a set of possible BMPs for consideration. For example, basin export concerns are often dominated by watershed loadings. Accumulation of contaminated sediment at the river mouth, terminal wetland protection, bioaccumulation, and dredging are the major issues. All of these are strongly linked to sediment delivery and will require BMPs which function during the spring runoff period, because this is the time when the majority of sediment is exported. Where basin export concerns are a priority, BMP selection will tend towards the use of ponds, because of the inefficiency of infiltration and vegetative BMPs during the spring period.

Instream/downstream use concerns are usually more dominated by daily ambient conditions and periodic rainfall or spill-driven shock loadings. The uses to be protected usually include fisheries and recreation. The key parameters are typically temperature, baseflow, structural channel integrity, dissolved oxygen, suspended solids (bedload), and bacteria. Nutrients are also of concern, but often as a second order problem. Spills and heavy metals from urban runoff are aspects which must be considered in BMP plan refinement, but they will rarely form a useful basis for BMP selection. Where instream uses are a priority, infiltration techniques and vegetative BMPs will usually be preferred because of temperature and baseflow maintenance concerns.

Local concerns are dominated by site specific conditions and resources. In most cases the concerns are oriented towards protection of existing resources and opportunities to create new resources. Groundwater contamination and preservation or creation of aquatic and terrestrial habitats are the primary issues. In addition, the impact of the BMPs on the proposed land use is a local issue. In certain cases local concerns may rule out the use of

certain BMPs as a primary measure (eg. infiltration in areas of significant aquifer recharge). In most cases however, local concerns can be addressed through design of the selected BMPs.

It should be recognized that the purpose of a BMP is to trap contaminants on-site and that in most cases contaminants are not destroyed. Concerns about accumulation of contaminants in local biota and pond sediment, or bacteria levels in retained surface water, are valid, but should not be an issue in BMP selection. These issues should be decided at the watershed planning level or on the basis of policy and if they are of sufficient concern within the context of the full watershed ecosystem, then BMPs should be limited to vegetative measures and development restrictions.

A combination of BMPs will often be necessary to address different levels of concerns. Because of the range of concerns possible from the local to the basin scale, and the potential for conflict, priorities should be set during the development of watershed plans or master drainage plans in order to guide trade-offs during BMP selection. In many instances regional scale facilities will address some of the concerns (eg. peak flow control) while local BMPs will address others (eg. baseflow preservation).

4.3 BMP Selection Process

Figure 4.1 is a schematic of a BMP selection process. BMP selection should be considered (with increasing detail) during watershed planning, development of the master drainage plan, and preparation of the stormwater management plan. While it is becoming increasingly common for municipalities to require master drainage plans, it is recognized that in some cases one or more of the higher level plans will not be available at the time that an individual development is ready to proceed. In such cases BMP selection can be collapsed into a single stage process which addresses the issues normally addressed at three planning levels. This single stage process is identified by the heavy lines on the flow chart. The elements of this single stage process represent the "critical path" in BMP selection and are discussed in detail in the following sections.

While there would appear to be an advantage to using the collapsed planning process (because there are fewer steps) this will not usually be the case. When BMP selection begins at the individual development level, the process will normally be expected to lead to more costly and more encumbering design requirements. The reasons for this are twofold. First, regulatory agencies should tend to set stricter performance requirements when strategic plans are not available, in order to protect for the highest possible use and to not limit the watershed's potential for rehabilitation. Second, in the absence of a master drainage plan, no regional facilities may be assumed. As a result, the local BMP plan must be designed to address all watershed concerns on which the site could impact. This will usually lead to larger facilities and a greater variety of BMP types being required.

The BMP selection process which follows is designed to allow an initial selection of a set of candidate BMPs based on uses and resources to be protected or improved. The intent is that the uses made of the watershed drive the BMP selection process, and that from the outset, the selection process be oriented towards creation of a BMP plan rather than a single-use facility.

The first steps in the process involve identification of concerns, setting of priorities and establishing the basis for the plan. This will ideally be done at the watershed planning or master drainage plan level. Consultation with agency approvals staff will be required, however, regardless of the existence of these documents. This consultation should occur early in the process.

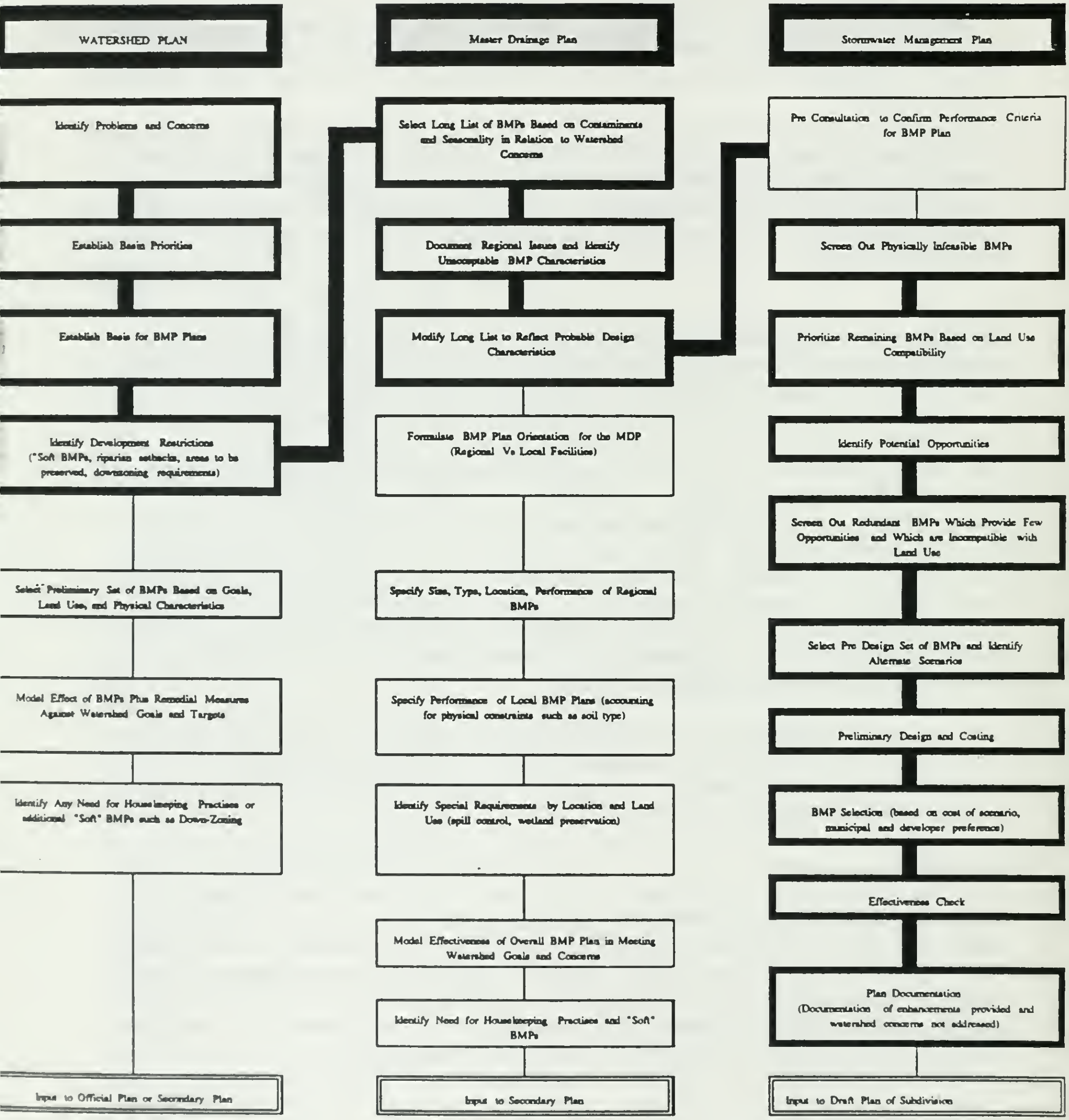
The next step is the selection of a long list of BMPs. Guidance is provided in subsequent sections in terms of typical selections and exclusions. This guidance is general in nature and exceptions may occur through innovative design. At this stage (within the master drainage plan process) the orientation between regional and local emphasis will be determined and performance characteristics for local and regional facilities will be specified.

This step is followed by a screening based on site specific considerations. Physical limitations of the site can eliminate certain BMPs. In addition, non-physical constraints are used to divide the feasible BMPs into two groups: those which seem to pose no problems; and those which may require special design or trade-offs. The criteria used for dividing BMPs based on non-physical constraints need not be overly rigorous and may actually be simply a matter of proponent preference. This is not a concern because non-physical constraints are not sufficient to eliminate BMPs. The BMP selection process is predicated on the requirement that the combination of BMPs selected address <u>all</u> identified use concerns unless <u>physical constraints</u> intervene.

The next step is an assessment of the opportunities presented by the remaining BMPs. At this stage a BMP which was given a second priority in the previous step and which offers no distinctive opportunities, may be eliminated, so long as it is not the sole effective means of dealing with an identified concern.

The BMPs which remain at this point are recommended for pre-design assessment in terms of costing, determination of maintenance requirements, sizing and siting. Typically by this stage, likely combinations of BMPs will have suggested themselves and it will often be more useful to evaluate a number of scenarios involving multiple BMPs rather than look at each BMP type individually. Based on the results of this assessment, the individual BMPs or scenarios are ranked primarily on the basis of cost, the fit with the development type, and the opportunities presented by the design. All scenarios evaluated must meet the entire list of concerns and any performance criteria which have been specified.

Figure 4.1 Integrated BMP Planning and Selection



The final product is a selected BMP or set of BMPs which can be submitted for approval and carried forward in design. The BMP selection process should be documented in the SWM plan along with any deficiencies in meeting established concerns.

Details relating to the major steps in the process are described below. The process is further illustrated by examples provided in Chapter 6.

1. <u>Establish Basis for BMP Plan</u>

The first step in the process is to establish the concerns which must be addressed by the BMPs and the concerns which must be considered in terms of potentially adverse impacts of certain BMPs. As stated previously, these concerns should ideally be established at the watershed planning level or master drainage plan level with broad agency and public involvement. The list of concerns will be specific to the watershed but may include:

<u>Basin Export Concerns</u>

Problem	Primary Concern	Major Season of Impact
Basin Loadings	Nutrients, metals, organics	Spring
Contaminant Accumulation (in sediment)	Nutrients, metals, organics	Spring
Aquatic Bioaccumulation	Metals, organics	--
Sediment Accumulation (dredging)	Suspended solids, eroded sediment	Spring
Wetland Protection (river mouth)	Metals, organics, sediment	Spring

<u>Instream Concerns</u>

Problem	Primary Concern	Major Season of Impact
Baseflow Preservation	low flow volume	Summer
Aquatic Food Source Protection	continuous flow, food input-riparian zone	--
Aquatic Habitat	stream morphology, sediment impacts	--

Fisheries Movement	continuous flow	Spring-Fall
Fishery Diversity	suspended solids, flow, nutrients	Spring-Fall
Wetland Protection	sediment, metals, organics, baseflow	Spring-Sum.
Recreation	Bacteria, turbidity, Aesthetic Parameters	Summer
Flooding/Erosion	Peak discharge	Watershed Dependent
Flooding	Volume	Watershed Dependent
Groundwater Recharge	infiltration	Summer
Streambank Erosion	hazard, sediment loss, habitat loss	Watershed Dependent

<u>Local Concerns</u>

Problem	Primary Concern	Major Season of Impact
Groundwater Contamination	chlorides, nitrates organics, oil & grease	Spring-Fall
Erosion (sheet)	sediment	Spring-Fall
Recreation	bacteria, safety	Summer
Aesthetics	nutrients, turbidity,	Summer
Preservation of "natural" Appearance		
Wetland Preservation	maintain existing resources	---
Terrestrial Habitat		
Bioaccumulation	metals, organics	---
Spills	variable	---

The problems and primary concerns associated with the basin export, instream, and local concerns indicate that different contaminants or problems, and different aspects of seasonality, come into play, depending on the area of focus. In many cases a single BMP will not be able to address all aspects and a combination of BMPs will be required. Even with the use of multiple BMPs, some conflicts will remain. It is important therefore that priorities be established clearly during the watershed planning process, so that this information can be fed into the BMP selection process.

Figure 4.2 indicates the relative effectiveness of different BMP's in dealing with different contaminants of concern, as well as quantity aspects and seasonal considerations. Figure 4.3 provides a generalized assessment of the utility of different types of BMPs, based on an overall consideration of all aspects. This figure is intended as a guide only, and it is recognized that innovative designs may upgrade the applicability of a BMP type.

Selection of a "long list"of BMP's can be made using these figures. The following general observations are made however, to assist in initial selection.

A. Where Basin Export Concerns Predominate:

Basin loading concerns are dominated by sediment-associated contaminants. The period of spring runoff represents the greatest loading from the watershed. Basin loadings can be handled either by detention storage or by control of sediment movement from construction sites and stream banks. For established subdivisions 'soft' controls e.g. control of pesticides and herbicides, de-icing chemicals should be employed to keep sediment clean. Source control and sediment control may be favoured since it does not attempt to store the huge volume of water naturally transported each spring and fall. However it will be challenging to implement source control and sediment control on a watershed scale. For the storage option, surface infiltration techniques or BMPs that rely on vegetation will not be effective. Similarly, use of wetland systems will provide limited benefits in such a case. Sub-surface infiltration BMPs will normally not be favoured because the high design sediment load will often lead to premature clogging of the facility.

B. Where Peak Flow Concerns Predominate:

In most cases where peak flow of low frequency storms (5 to 100 year return period) is a major issue, some form of surface storage BMP will be required. Experience indicates that in most cases, regional facilities are more efficient than localized storage. Local BMPs will often allow down-sizing of regional BMPs. For more frequent storms (eg < 2 year) surface storage, underground storage, or infiltration facilities may be used. Vegetative BMPs, while providing benefits due to higher natural infiltration and interception, cannot effectively address peak flow concerns on their own.

Figure 4.2 Relative Effectiveness of BMPs by Contaminant

BMP TYPE	Sus. Solids	Total Phos.	Total Nit.	Oxygen Demand	Heavy Metals	Bacteria	Spills	Temper-ature	Seasonal Effectiveness	Overall Effectiveness
Surface Storage BMPs										
Dry Ponds	○	○	○	○	○	○	○	◆	low	low
Extended Detention Ponds	●	◆	◆	◆	●	◆	○	○	medium	medium
Retention (wet) Ponds	●	◆	◆	◆	●	◆	●	○	high	high
Artificial Wetland	◆	●	●	◆	◆		○	○	low	medium
Storage Tanks	●	◆	◆	◆	●	◆	●	●	high	high
Infiltration BMPs										
Infiltration Basins	◆	●	●	●	●	●	○	●	low	high
Infiltration Trenches	◆	●	●	●	●	●	○	●	medium	high
Seepage Trenches	○	◆	◆	◆	◆	◆	○	◆	medium	low
Porous Pavement	◆	●	●	●	●	●	○	●	low	high
Vegetative BMPs										
Buffer Strips	◆	○	○	◆	◆	○	○	◆	low	low-medium
Grass Swales	○	○	○	○	○	○	○	○	low	low
Filter Strips	●	◆	◆	●	●	○	○	◆	low	medium
Soft BMPs										
Conservation / Restoration	○	○	○	◆	◆	○	○	◆	low	low-medium
Special Purpose BMPs										
Oil/Grit Separator	●	○	○	○	◆	○	●		high	low-medium
Catchbasins	◆	○	○	○	◆	○	◆		high	low-medium
Treatment										
U-V Disinfection	○	○	○	○	○	●	○		na	medium (bacteria)

High Potential ● Medium Potential ◆ Low Potential ○

Figure 4.3
Generalized Utility in Addressing Concerns

BMP TYPE	Primary Concerns														
	Peak Flow & Erosion				Fisheries				Recreation		Habitat				
	100 Year	10 Year	2 Year	Infiltration	Spring Sediment	Sus. Solids	Temperature	Dissolved Ox.	Spills	Bacteria	Turbidity	Nutrients	Aquatic Habitat	Ter. Habitat	Preservation
Surface Storage BMPs															
Dry Ponds	X	X	X												
Extended Detention Ponds	X	X	X		X	X					X		X		
Retention (wet) Ponds	X	X	X		X	X			X	X	X		X		
Artificial Wetland						X					X	X	X	X	
Storage Tanks			X			X	X	X	X	X	X				
Infiltration BMPs															
Infiltration Basins			X	X		X	X	X		X	X	X		X	
Infiltration Trenches			X	X		X	X	X		X	X	X			
Seepage Trenches				X											
Porous Pavement			X	X		X	X	X		X	X	X			
Vegetative BMPs															
Buffer Strips				X		X	X				X	X		X	X
Grass Swales				X		X					X				
Filter Strips				X		X					X			X	
Soft BMPs															
Conservation/Restoration				X		X	X				X	X		X	X
Special Purpose BMPs															
Oil/Grit Separator						X			X		X				
Catchbasins															
Treatment															
U-V Disinfection										X					

NOTE : INNOVATION CAN UPGRADE APPLICABILITY OF BMP TYPE

C. Where Groundwater Contamination Concerns Predominate:

The greatest concern in groundwater contamination results from soluble contaminants such as chlorides and nitrates. Heavy metals are rarely of concern because studies indicate they typically migrate only a short distance through the soils. There is relatively little information on groundwater contamination by organic chemicals as a result of infiltration of surface runoff. None of the BMPs are effective in removing chlorides. As a result, any BMPs which are designed to transmit surface runoff into the groundwater should be excluded from use in areas where groundwater contamination is a predominant concern.

In some instances concerns for groundwater protection and other concerns such as baseflow preservation or temperature control may conflict. Groundwater concerns should take precedence, but there may be opportunities to utilize infiltration techniques on a limited scale. The main opportunities would include:

- use of separate pervious/impervious area drainage systems (lot drainage, roof drainage may be directed to infiltration systems, while road drainage is directed to a non-infiltration system).

- infiltration systems may be designed in some instances to discharge to surface waters, through seepage. Design must prevent a flow path to the groundwater aquifer.

D. Where Fisheries Concerns Predominate:

Various design considerations besides sedimentation will have to be taken into account in BMP design where fisheries are a prime concern (suspended solids, temperature, dissolved oxygen). In general, however, on-line ponds are not a desirable BMP in such instances. They typically impede fish movement and the transmission of food from upper reaches, block fish migration, and increase the temperature of the water. In specific areas these problems can be reduced (fishways, maintenance of local food source, shading requirements).

E. Where Habitat Preservation Concerns Predominate:

Preservation of wetlands and significant habitat areas requires utilization of existing resources to the greatest extent possible and usually leads to greater reliance on vegetative BMPs. Two aspects of BMP selection may be noted. First, use of land intensive BMPs such as wet ponds will normally not be appropriate. Second, some form of pretreatment BMP will often be required to protect the resource (i.e. a natural wetland) if it is to be used as part of the treatment system.

2. <u>Identification of Probable Design Characteristic of BMPs</u>

At this stage in the process, a "long list" of BMP options has been selected. Many of these will be useful in meeting one concern while causing problems related to another (eg. temperature in wet ponds whose primary function is efficient control of exported sediment). Before proceeding with screening, it is therefore expected that the designer will establish required design characteristics of BMPs (eg. bottom draw, aeration, and average 3-5 m depth, or specific vegetation and surface area configuration requirements, for a wet pond to prevent warming of the water) or suggest combinations of BMPs (which would subsequently be treated as a group) in order to render the BMP acceptable, in terms of not contributing to problems or extrapolating the utility of the BMP.

Within the context of a Master Drainage Plan, this is the stage at which the regional/local orientation of the BMP plan is established. Those concerns which will be addressed through regional facilities are identified, as are those which will be addressed through local measures. The size, type, location, and performance criteria of regional facilities are determined, as is the required performance of local BMP measures. Special requirements relating to land use (eg spill control) or regional resources (eg riparian habitat, wetland or woodlot preservation) are specified.

If a Master Drainage Plan has not been completed, then the performance criteria for the local BMP, as a whole, plus any special requirements should be established through consultation with the regulatory agencies and the municipality. Every effort should be made to encourage the development of Master Drainage Plans. Experience has shown that delays will often ensue at this stage (in the absence of an MDP) because agency and municipal staff lack the direction which is provided from the studies conducted in a master drainage plan. Uncertainties result in delays or stipulation of stricter performance criteria.

3. <u>Screen Selected BMP's Based on Site Characteristics</u>

The site characteristics and the nature of the development will determine the applicability and utility of many of the BMPs. In this step, the list of potential BMPs (selected on the basis of the problem to be resolved in step 1) are screened to prioritize applicable BMPs and eliminate those which are not feasible. An important aspect of the screening is to identify the problems which will not be addressed because of elimination of BMPs. Other means must be sought to address these concerns in the overall planning process.

Screening should be conducted first on the basis of physical constraints such as soil type, slope, water table depth and proximity to bedrock. These physical constraints will typically be overriding and often insurmountable through design, leading to BMP elimination. The potential for these physical constraints to limit BMP use is provided in Figure 4.4. More specific guidance is provided in Figure 4.5 for soil type constraints. Figure 4.5 is a reproduction from Schueler (1987), and is to be confirmed for Ontario design conditions in the second phase of this study.

The BMPs that remain after this initial screening should be assessed based on size of development, land use and environmental considerations. Figures 4.6 and 4.7 are provided to aid in this assessment. The latter figure is a reproduction from Schueler (1987) and is provided as a preliminary guide pending confirmation in phase 2 of this project.

Failure at this level of screening may not necessarily eliminate the BMP type from further consideration, but the BMP would generally be given a lower priority for investigation because special designs or trade-offs would be required.

The result of this screening step is a reduced set of BMPs, divided into first and second priority groups; and a list of problems which will exist because there are no feasible BMPs available to address them.

4. Assessment of Opportunities

An important goal in the selection of a BMP or a system of BMPs is to maximize the multi-use aspects of the design. To some extent this is accomplished by using the problems to be addressed as the basis for the initial selection of BMPs in step 1. It is useful however to consider the opportunities presented by the different BMPs which have passed the screening process in order to suggest refinements to the priority 1 BMPs and to flag the priority 2 BMPs which should receive special consideration. Priority 2 BMPs which do not present significant opportunities and which do not represent the sole effective means of addressing a particular concern, may be screened out at this stage.

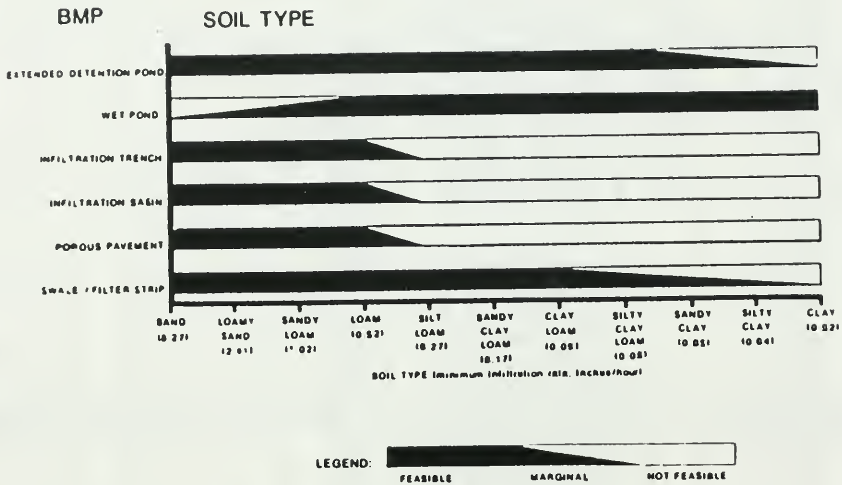
The opportunities provided by different BMPs are listed in Figure 4.8. A detailed listing of the advantages and disadvantages of different BMPs is provided in Appendix F.

Figure 4.4 Potential Physical Constraints Affecting BMP Feasibility

BMP TYPE	Soil Type	Slope	High Water Table	Bedrock
Surface Storage BMPs				
Dry Ponds	○	○	○	◆
Extended Detention Ponds	○	○	○	◆
Retention (wet) Ponds	○	○	○	◆
Artificial Wetland	◆	○	○	◆
Storage Tanks	○	○	●	●
Infiltration BMPs				
Infiltration Basins	●	◆	●	●
Infiltration Trenches	●	●	●	●
Seepage Trenches	●	○	●	●
Porous Pavement	●	●	●	●
Vegetative BMPs				
Buffer Strips	○	◆	◆	◆
Grass Swales	○	●	●	◆
Filter Strips	○	◆	◆	◆
Soft BMPs				
Conservation /Restoration	○	○	○	○
Special Purpose BMPs				
Oil/Grit Separator	○	○	●	●
Catchbasins	○	○	○	○
Treatment				
U-V Disinfection	○	○	○	○

High Potential ● Medium Potential ◆ Low Potential ○

Figure 4.5 Soil Permeability Restrictions for BMPs



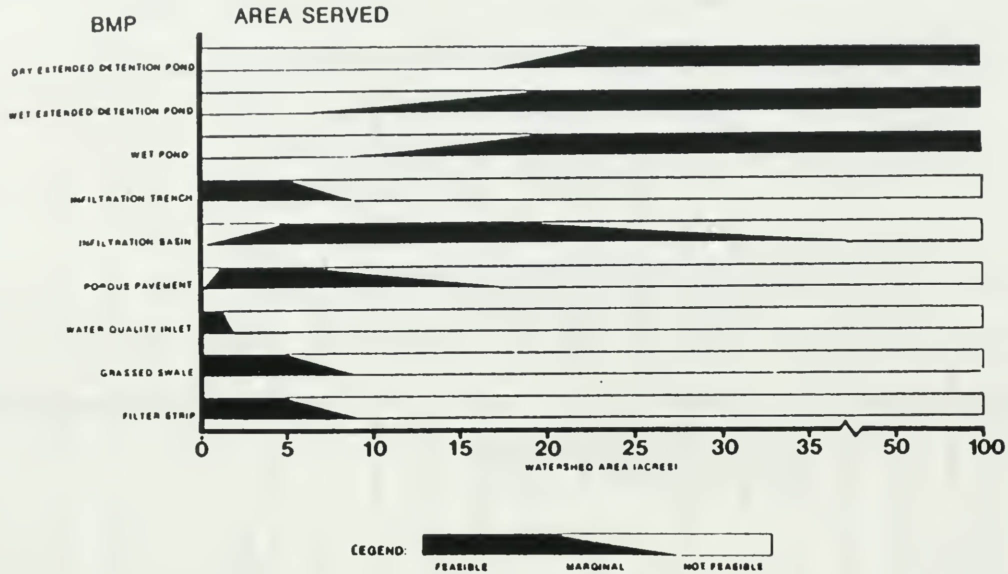
Source: Schueler, 1987

Figure 4.6 Land Use and Environmental Constraint Potential

BMP TYPE	Space Consumption	Foundations	Land Use Type	Pretreatment Required	Thermal Impacts
Surface Storage BMPs					
Dry Ponds	●	○	○	○	○
Extended Detention Ponds	●	○	○	○	◆
Retention (wet) Ponds	●	○	○	○	●
Artificial Wetland	●	○	○	●	●
Storage Tanks	○	○	○	○	○
Infiltration BMPs					
Infiltration Basins	◆	◆	○	●	○
Infiltration Trenches	○	●	○	●	○
Seepage Trenches	○	●	●	○	○
Porous Pavement	●	●	●	◆	○
Vegetative BMPs					
Buffer Strips	○	◆	◆	○	○
Grass Swales	○	◆	●	○	○
Filter Strips	○	◆	◆	○	○
Soft BMPs					
Conservation / Restoration	◆	○	◆	○	○
Special Purpose BMPs					
Oil/Grit Separator	○	○	●	○	○
Catchbasins	○	○	○	○	○
Treatment					
U-V Disinfection	●	○	○	◆	◆

High Potential ● Special Design/Siting Required ◆ Low Potential ●

Figure 4.7 Typical Watershed Area Restrictions for BMPs



Source: Schueler, 1987

Figure 4.8 Potential Opportunities Presented by BMPs

BMP TYPE	Low Flow Maint.	Stream Erosion	Aquatic Habitat	Wildlife Habitat	Thermal Control	Landscape Enhance.	Recreation Benefits	Public Safety	Aesthetics	Public Accept.
Surface Storage BMPs										
Dry Ponds	○	●	○	●	●	◆	●	◆	◆	◆
Extended Detention Ponds	○	●	◆	●	○	◆	●	◆	◆	◆
Retention (wet) Ponds	○	●	●	●	○	●	●	◆	◆	●
Artificial Wetland	○	○	●	●	○	◆	◆	◆	◆	◆
Storage Tanks	○	●	○	○	●	○	○	●	●	◆
Infiltration BMPs										
Infiltration Basins	●	◆	○	◆	●	○	○	●	◆	◆
Infiltration Trenches	●	◆	○	○	●	◆	◆	●	●	●
Seepage Trenches	●	◆	○	○	●	○	○	●	○	●
Porous Pavement	●	◆	○	○	●	○	○	●	○	●
Vegetative BMPs										
Buffer Strips	◆	◆	○	●	●	◆	○	●	◆	●
Grass Swales	◆	○	○	◆	●	◆	○	●	◆	●
Filter Strips	◆	○	○	●	●	◆	○	●	◆	●
Soft BMPs										
Conservation / Restoration	◆	◆	○	●	●	◆	◆	●	◆	●
Special Purpose BMPs										
Oil/Grit Separator	○	○	○	○	○	○	○	●	●	●
Catchbasins	○	○	○	○	○	○	○	●	●	●
Treatment										
U-V Disinfection	○	○	○	○	○	○	○	●	○	●

High Potential ● Medium Potential ◆ Low Potential ○

5. Selection of a Set of BMPs

At this stage all BMPs which are physically infeasible or which may be difficult to accommodate in the development, while offering no significant opportunities, have been screened out. Concerns which cannot be addressed through the use of BMPs, because of physical constraints, have been identified.

The final step in the predesign selection of BMP's involves identification of the maintenance requirements, preliminary costing (both O & M and capital), preliminary sizing and siting. In most cases combinations of BMPs will suggest themselves, either because of the need to address multiple concerns or because of potential opportunities. In general it is advisable to formulate several alternate scenarios which allow the evaluation of different approaches. Each scenario evaluated must be sized and designed to meet the performance criteria for the site a whole.

The information generated is combined with the information on opportunities presented and the BMPs or combinations of BMPs are ranked. Ranking of the BMPs will, of necessity, involve professional judgement and qualitative trade-offs (eg. capital cost vs maintenance cost; cost vs opportunities presented).

The selected set of BMPs are compared to the original set of concerns to be addressed and required performance criteria, as a final check. The only valid reason for not addressing a concern should be physical infeasibility. In some cases effectiveness may be an issue and performance criteria may not be available. Vegetative BMPs applied alone for instance, may address a set of concerns, but will usually not be effective for sediment control if development density is high. As a general rule, the percentage of site runoff volume treated by vegetative BMPs alone should not exceed the ratio of pre development imperviousness to post development imperviousness. This rule does not limit the use of vegetative BMPs in conjunction with other, more effective measures.

The result is a final set of BMPs which will form the elements of a BMP plan. The plan, which should include documentation of the selection process, a list of concerns which cannot be addressed by BMPs, potential "soft" BMP measures or housekeeping practices to address these concerns, and specifics on design elements to be addressed (eg. temperature control in wet ponds) would be submitted to the approval agencies for review and approval prior to final design. It is anticipated that the BMP plan would form a subcomponent of the overall stormwater management plan for the development.

4.4 Performance Criteria

The design of an individual BMP or a BMP system should be based on the existing or desired uses of the receiver and the goals established for the watershed as a whole. Instream and loading targets should be established during the development of the watershed plan, using technical data and inventories of resources, in conjunction with extensive consultation with regulatory agencies, municipalities and the public.

The selected targets for instream water quality should be translated into a set of performance criteria which will govern the effectiveness of local BMP plans. The list of performance criteria will vary by watershed and may vary by site depending upon localized concerns. An example list of performance criteria is provided below, for illustrative purposes only. Actual performance criteria should be established during Watershed and Master Drainage Planning and confirmed/revised by the regulatory agencies at the Stormwater Management Plan level.

Primary Concern	Parameter	Performance Criteria
Flooding	100 Year	Pre/Post Peak Match
	10 Year	" "
	2 Year	" "
Spring Load	Suspended Solids	12-24 Hr retention of peak (spring) daily flow or 70% reduction in SS loading
Baseflow	Infiltration	infiltration to be at least 80% of the pre development condition on an annual basis
Fisheries	Suspended Solids	removal of SS down to 40u for a 2 hr, 25mm storm or 70% reduction of 40u particle size loading
	Temperature	no net increase on a site basis
	Dissolved Oxygen	90% of saturation (after discharge) for surface storage BMPs
	Spills	residential: minimum capture of 500 l industrial: as per MISA BMP requirements
Recreation	Bacteria	maximum number of violations per season at the downstream beach
	Turbidity	see Fisheries SS criteria
	Nutrients	see Fisheries SS criteria
Aquatic Habitat	Streams	maximize natural channel design
	Wetlands	no net loss
Terrestrial Habitat	Riparian Strip	minimum 15 m buffer along watercourse (each side)

In the absence of watershed-specific targets the regional criteria established by regulatory agencies for quantity control, erosion control, buffer strips, etc. should form the minimum for design. In addition, however, all possible efforts should be made to specify additional criteria which may be used to guide BMP selection. In most cases the best criteria will be physical in nature and will avoid chemical limits.

In terms of pollutant removal criteria for specific BMPs, current data in the Ontario experience is insufficient to suggest design targets for most water quality parameters. A range of removal efficiencies is available for ponds in Ontario and for other BMPs elsewhere. The removal efficiencies in the literature are very case-specific. Additional monitoring and research is needed before specific design criteria linked to target discharges can be established for nutrients, metals, and organics.

At the present time design of BMP facilities must rely upon the professional judgement of designers and approval staff. The Ministry of the Environment is developing guidelines (Ministry of the Environment and Ministry of Natural Resources Draft Interim Stormwater Quality Control Guidelines for New Development, 1989) to provide direction for design targets for stormwater pond discharges. A draft discussion paper on these guidelines (1989) suggested using specific retention times for design storms in order to achieve a particular level of settling for suspended solids or a percentage of die-off for bacteria.

More detailed design criteria (i.e. specifying targets for specific parameters such as metals) are not warranted given the current state of design experience. Fairly extensive guidance is available on sizing, configuration and other physical design characteristics, but these are based on empirical assessment of facility histories. The guidelines which are available do not relate design criteria to water quality concentration targets. Additional research and monitoring of a range of facilities is necessary prior to any attempt to explicitly set quality discharge targets.

In most cases where there are not groundwater concerns the designer should seek to maximize infiltration to the extent feasible. Efforts to match pre-development hydrologic response is the first and most important step in water quality management. Reduction of surface runoff volume will yield benefits in the sizing of services and "end-of-pipe" BMPs such as retention ponds. It will reduce loads transmitted, maintenance costs and instream impacts (lower runoff volume mixing component).

5.0 BMP DESIGN CRITERIA

5.1 Hydrologic Design Criteria

In order to mitigate water quality degradation, a BMP must be designed to accommodate the majority of storm events which contribute to the degradation.

Specific design storms are currently used to size stormwater quantity ponds. Specific storm events are used since quantity ponds mitigate the effects of large infrequent storm events such as the 2, 5, 10, 25, and 100 year return period storms. This is opposite to the intent of water quality features since the frequent events are of greatest interest.

Therefore, 3 analyses were made to investigate the appropriateness of different water quality design criteria :

1. Precipitation Analysis - Design Storm
2. Stormwater Runoff Analysis
3. Continuous Simulation Analysis

5.2 Precipitation Analysis

Daily precipitation records from Bloor Street (Toronto) were analysed to determine an appropriate runoff volume for a BMP design. Twenty years of record were analysed for the period from 1967 to 1986.

Figure 5.1 shows a precipitation depth-duration curve for the Bloor St. gauge. Figure 5.1 indicates that 90 % of the daily precipitation values for the twenty year period were less than or equal to 15 mm. This is misleading, however, since 90 % of the days do not produce 90 % of the precipitation volume. Figure 5.2 presents the percentage of total precipitation which occurred for days with a precipitation depth less than or equal to a specific depth. This figure shows that days with a precipitation depth less than or equal to 15 mm accounted for only 55 % of the total precipitation (90 % of the days with precipitation recorded a depth less than or equal to 15 mm). In other words, days with precipitation greater than the BMP design storm (15 mm) would account for approximately 50 % of the total annual precipitation depth.

Figure 5.3 explains why this anomaly occurs. The majority of precipitation events are small (less than 3 mm). These small events, produce a small cumulative precipitation total, whereas the days with significantly greater precipitation (> 25 mm), while small in number, produce a significant percentage of the total precipitation (Figure 5.4).

Figure 5.2 indicates that the BMP design should be based on a daily precipitation depth of 34 mm if the objective was to control 90 % of the total precipitation volume. This level of protection approximates the control of a 2 year storm.

Figure 5.1 Precipitation Depth Duration Curve

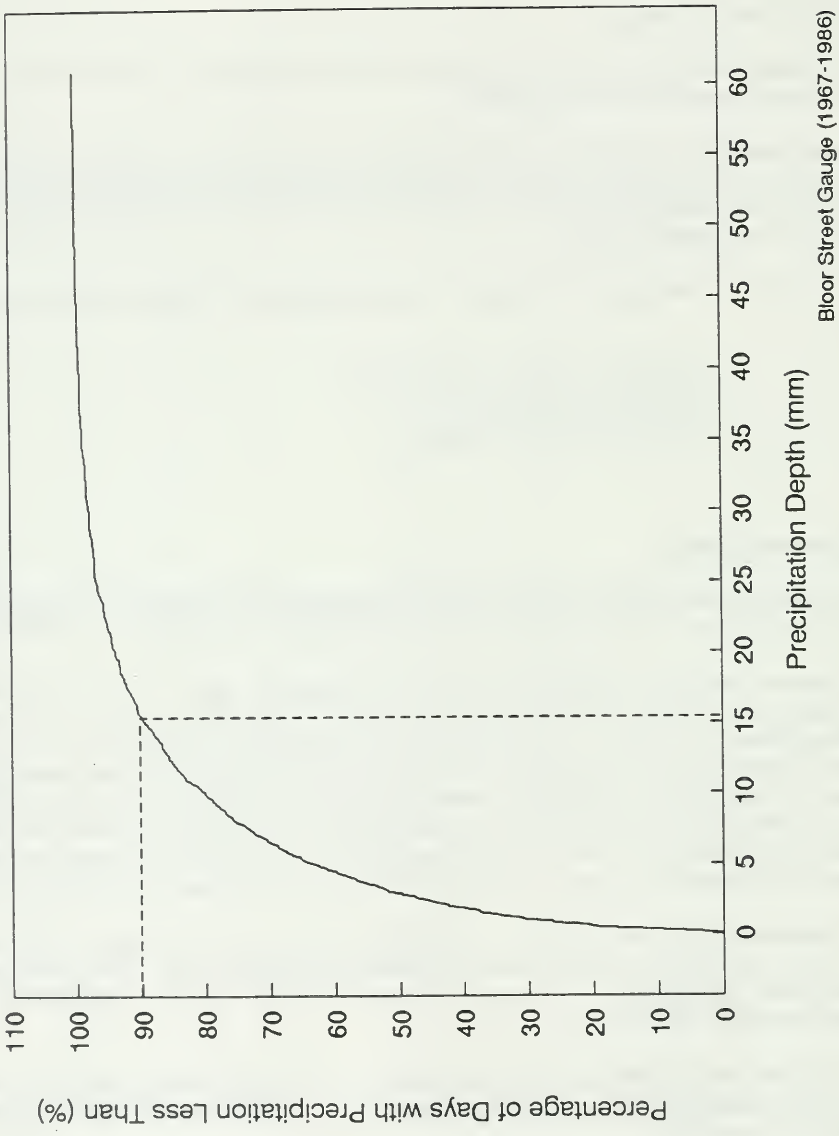


Figure 5.2 Relationship of Daily Precipitation Depth to Total Precipitation

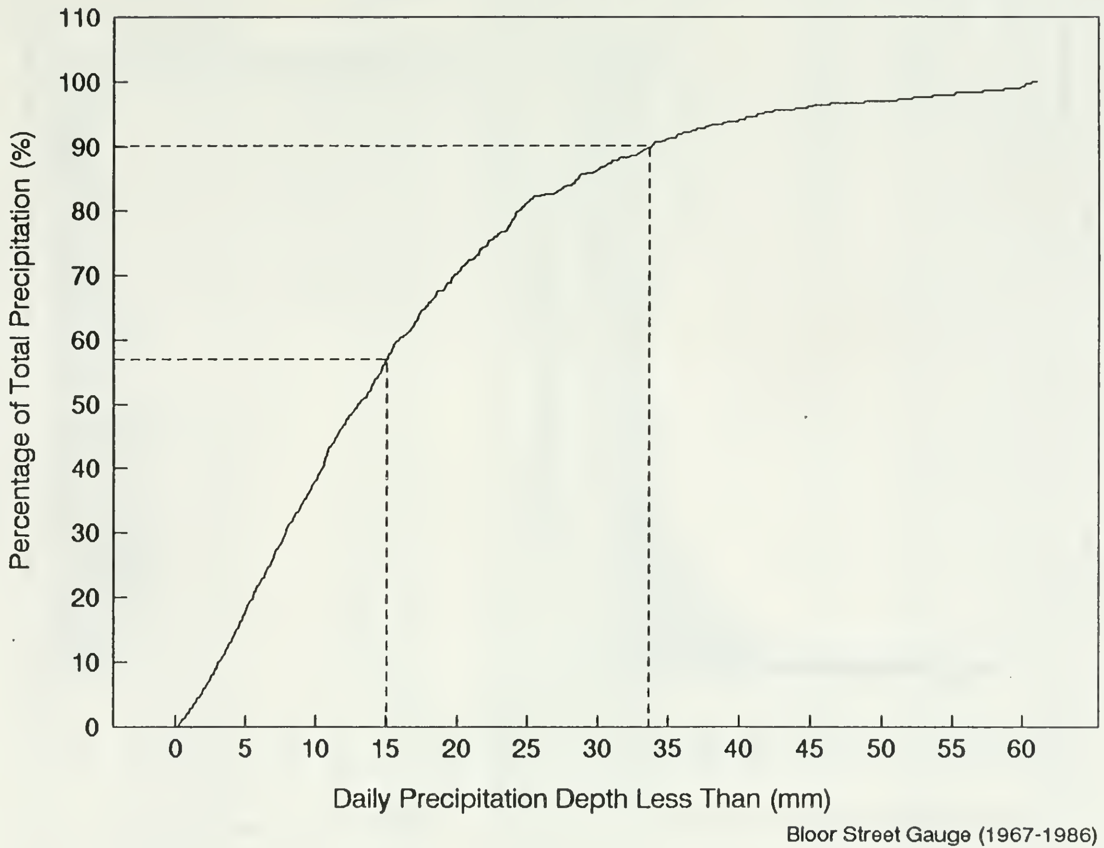
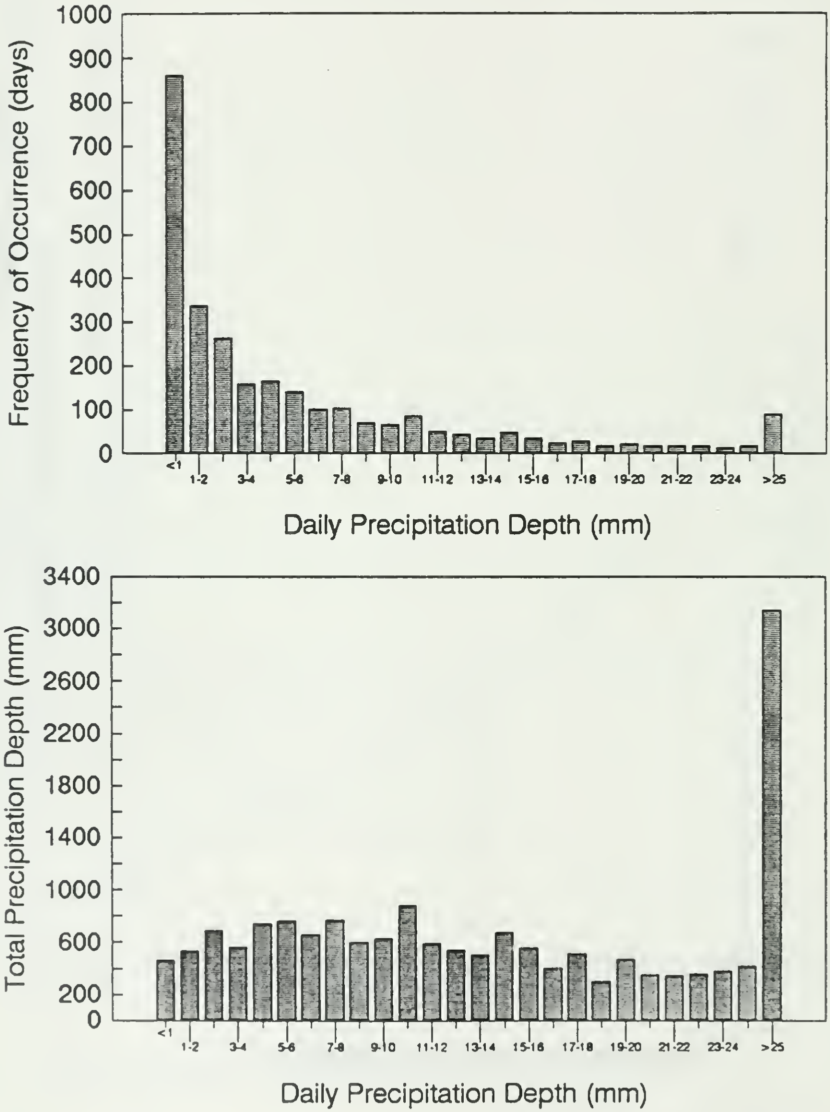


Figure 5.3 Frequency versus Cumulative Magnitude of Precipitation Depths



Bloor Street Gauge (1967-1986)

A significant problem in using precipitation records to determine a design storm is snow accumulation/melt. The use of precipitation records does not account for the accumulation of precipitation during the winter months and its subsequent release during the spring freshet. Current standard event simulation models cannot accommodate freshet conditions due to the requirement for a starting snowpack depth and the use of temperatures (at least) to determine the timing of the melt.

Another problem with the design storm approach to BMP planning is that it does not account for series of storms. Several back to back storms, all of which being less than the design storm, could create an overflow at the BMP.

Therefore, the use of a water quality design storm and event simulation is inappropriate for the design of BMPs under Canadian conditions.

5.3 Stormwater Runoff Analysis

The same 20 years of record (1967-1986) were analysed for the streamflow gauge on the Black Creek (a tributary of the Humber River) in the Greater Toronto Area. Baseflows were approximated by analysing streamflow for days during dry periods (no precipitation either on the day before or after that used for baseflow estimation). The baseflow values were reviewed manually to validate the estimates since the precipitation values were not a reliable indicator of runoff during the winter and spring seasons. Separate baseflow values were compiled for each month of each year to account for the variable nature of baseflow (both on a seasonal and annual basis).

The baseflow values were then subtracted from the total streamflow values to determine the direct runoff values. Events were defined by consecutive days with direct runoff. Separate runoff-duration curves were compiled for each month of the year for the following runoff parameters :

- runoff event volume (depth)
- runoff event duration (days)
- inter-event times between runoff (days)

Figure 5.4 demonstrates the seasonality of runoff. Event runoff depths for the months of March and April are much greater than any other time of year. The same seasonality trend occurs for event duration as indicated by Figure 5.5. This suggests that the spring runoff is spread out over several days, whereas the summer events occur for a shorter period of time. The inter-event time does not show a seasonality effect (Figure 5.6).

The seasonality of runoff can be further demonstrated by Figure 5.7. Although there are substantially more runoff events during the summer months, the spring months of March and April produce much more runoff volume.

Figure 5.4 Seasonality of Stormwater Runoff

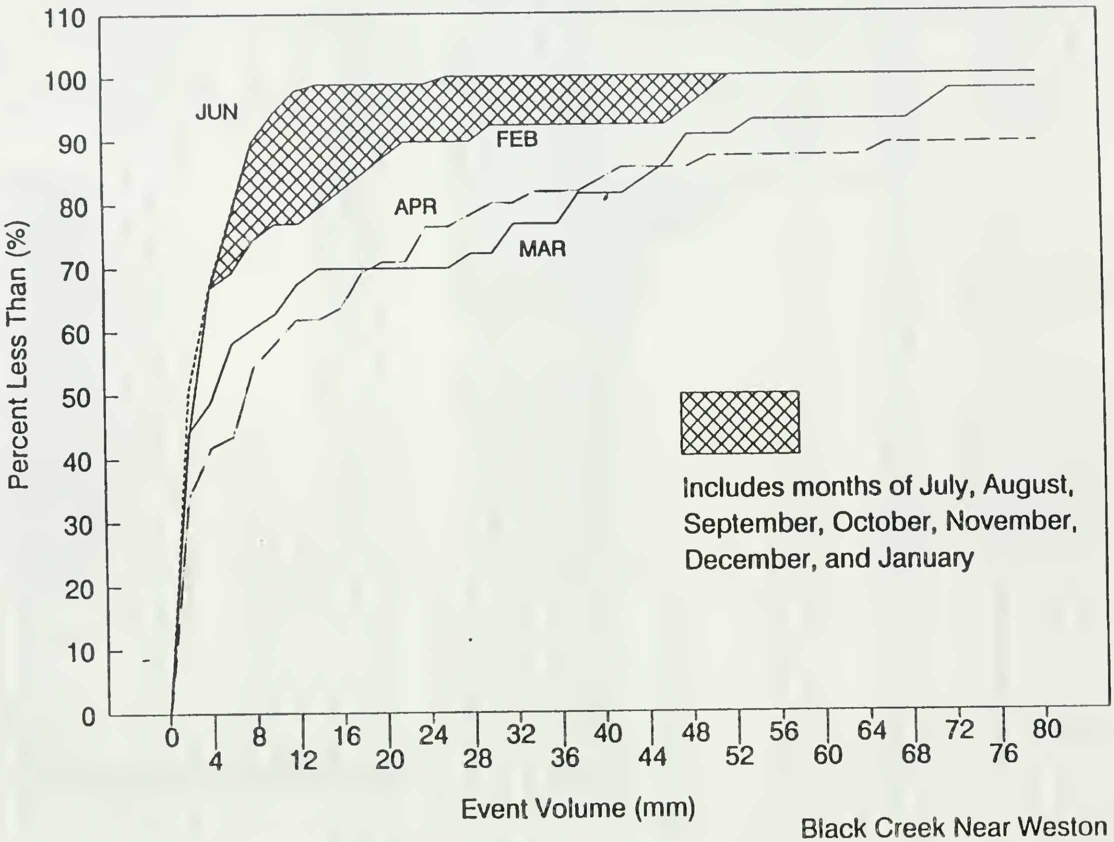


Figure 5.5 Seasonality of Runoff Event Durations

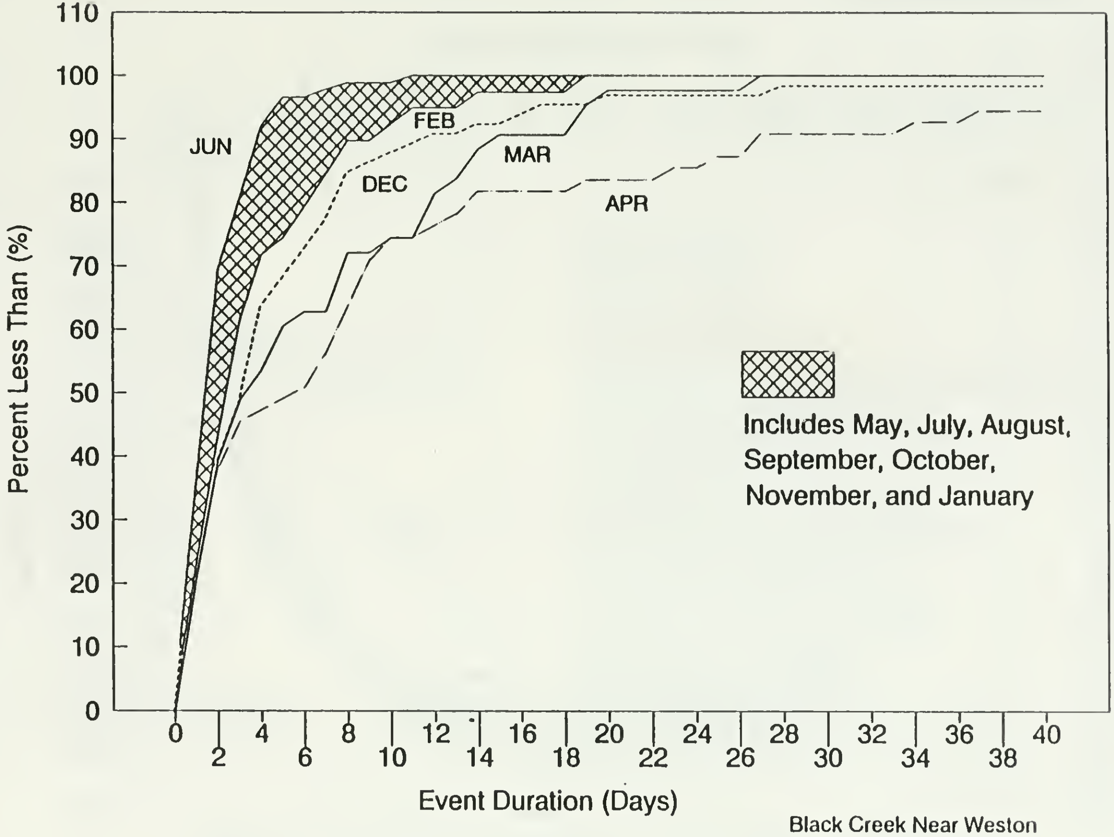


Figure 5.6 Seasonality of Inter Event Durations

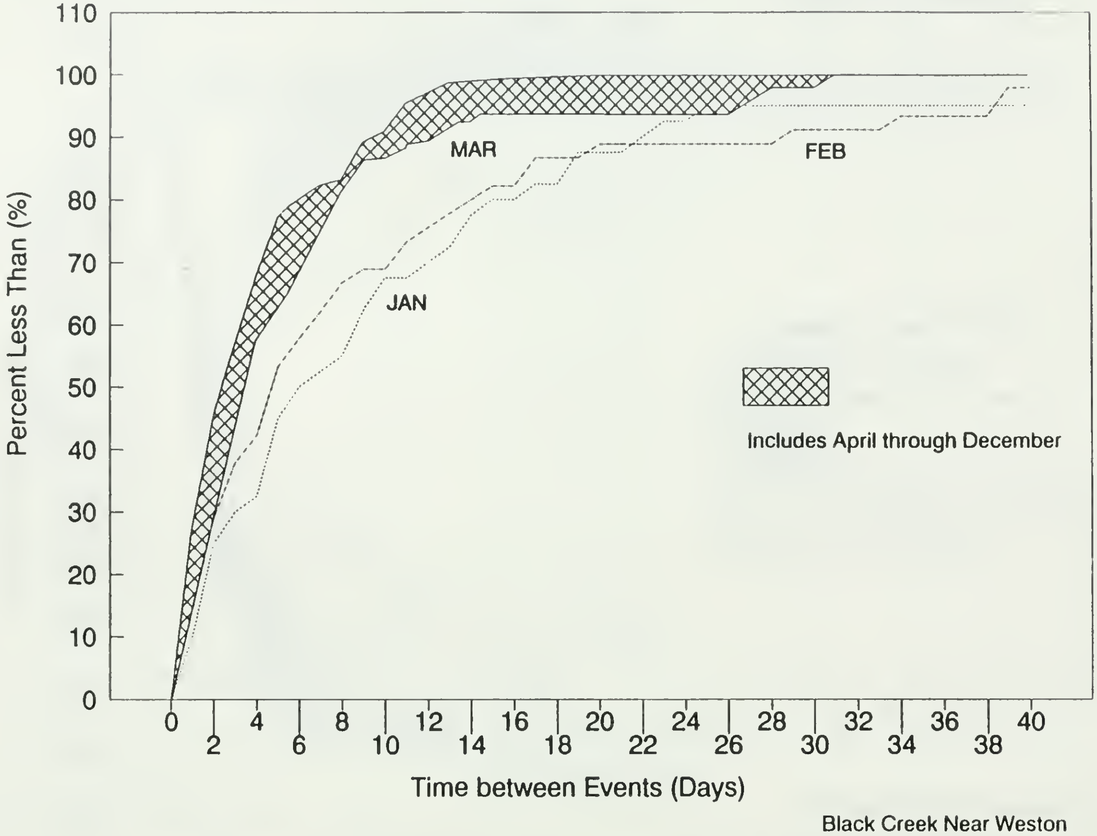
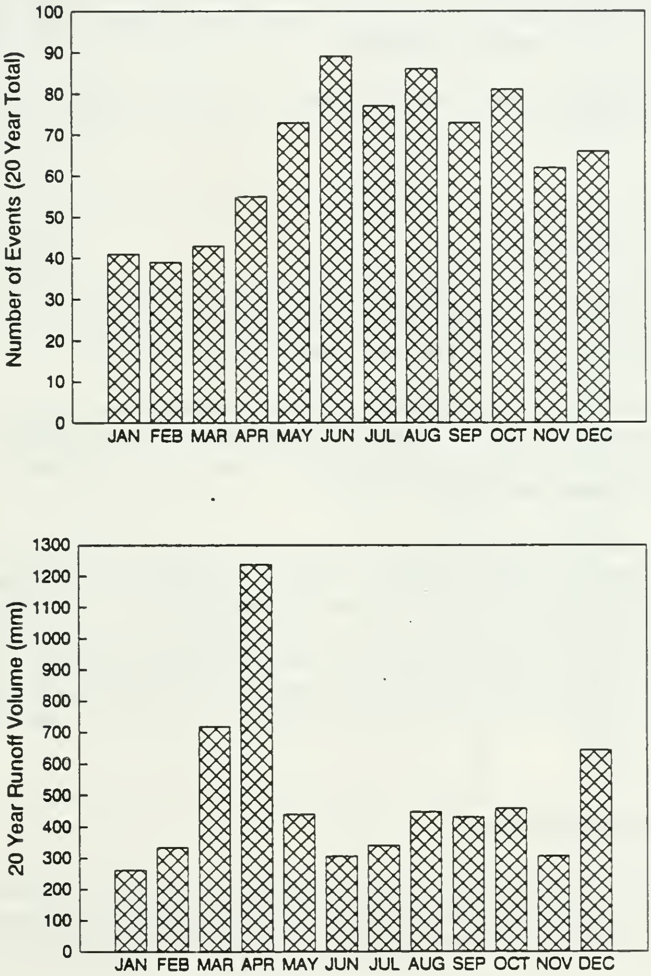


Figure 5.7 Frequency versus Magnitude of Stormwater Runoff Events



Black Creek Near Weston

This analysis suggests that there should be at least two design runoff events to accommodate differences in runoff due to seasonality. The analysis is incomplete, however, since the spring events occur over a longer duration than the summer events. This difference in event intensity will affect the required design storage volume depending on the required retention time. The desired retention time would be dependent on the nature of water quality concerns and the type of BMP chosen. Summer concerns such as baseflow augmentation require infiltration techniques which require longer retention times than surface storage techniques (ponds) due to the nature of conveyance.

This type of analysis (design event) also does not account for a sequence of runoff events, and is therefore inappropriate for BMP design.

5.4 Continuous Runoff Analysis

Continuous analysis involves the use of precipitation and other meteorological inputs to derive stormwater runoff for the entire year(s). Accordingly, most processes of the hydrologic cycle must be simulated such as snow accumulation and melt, evapotranspiration, infiltration, and runoff.

The 20 year series (1967-1986) of runoff (Section 5.3) from the Black Creek gauge could be regarded as the output from a continuous simulation model. A fortran program was written to analyse the runoff series with varying times of retention. Any period of time could be analysed within the year to differentiate between summer and spring/fall concerns.

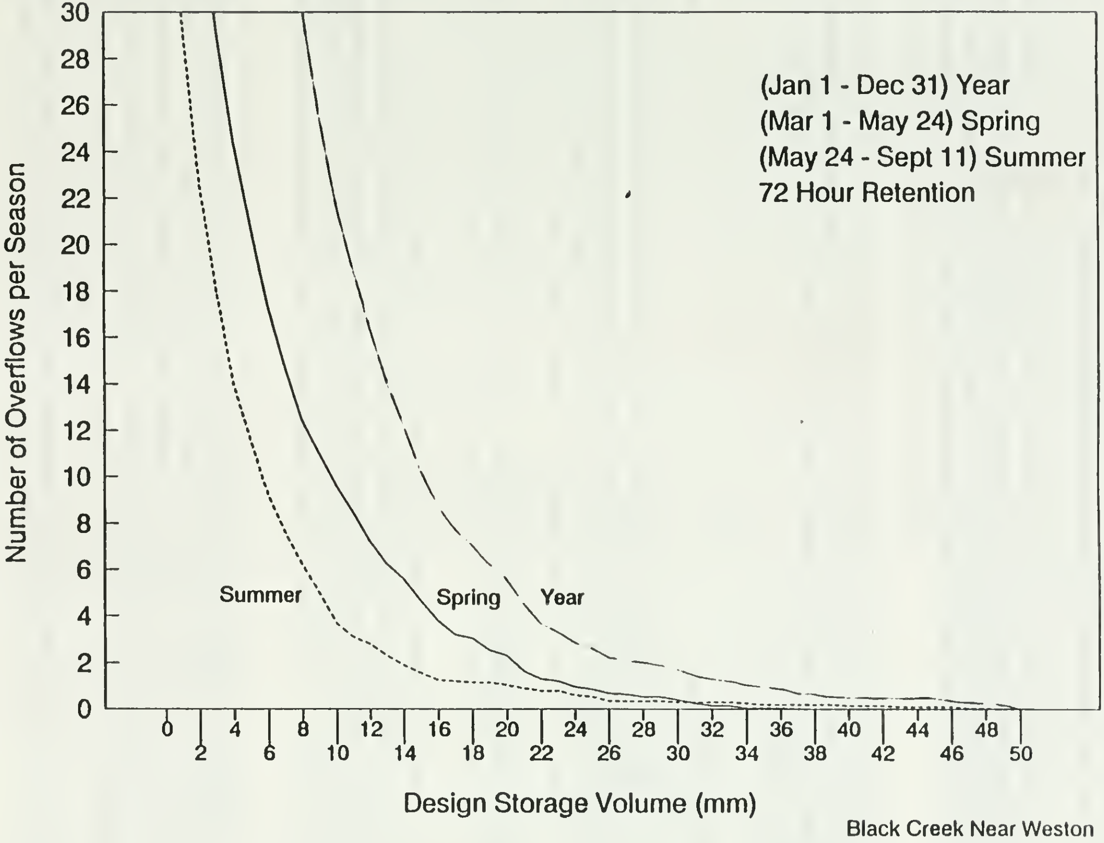
The fortran program assumes a first in/first out (plug flow) relationship between the inflow and outflow from the storage. This relationship also applies to overflows. Overflows from the storage are subtracted from water which has been in storage for the longest period of time. This would probably occur in a pond, since the overflow spillway is usually located near the outlet of the pond, but would not occur for an infiltration trench where the storage fills and any subsequent runoff by-passes the trench. Nonetheless, the number of overflows, and overflow volume, are correctly quantified for both types of BMPs. The number and volume of overflows were recorded for the 20 year period of record for different storage volumes and retention times.

5.4.1 Spring versus Summer Concerns

Figure 5.8 presents the difference in design volumes for the summer (May 24 - September 11), and spring (March 1 - May 24), as opposed to the entire year. This figure demonstrates the seasonality effect of runoff since more storage volume is required in the spring than the summer to meet the same number of storage overflows.

Figure 5.8 was based on a 72 hour retention time of daily runoff volumes. Seventy-two hours was used since it represents the maximum allowable time for infiltration of the storage volume (Schueler, 1987).

Figure 5.8 Seasonality of Stormwater Quality Storage Volumes



It also corresponds to the retention time for bacteria control (90 % die-off) in wet ponds. It is anticipated, however, that the effluent stormwater from an infiltration BMP would meet the M.O.E. body contact recreation criteria, as long as flow did not by-pass the infiltration device.

It would not be appropriate to use a 72 hour retention time during the spring period since infiltration techniques have questionable utility (subject to research) in the spring and bacteria is not a spring concern. Therefore, the spring period (March 1 - May 24) was analysed with a 24 hour retention time. Twenty-four hours was chosen since it represents the time required for the settling of the majority of 40 μm size particles.

A graph of number of overflows versus design volume is presented in Figure 5.9 for 72 hours of retention during the summer and 24 hours of retention during the spring. This figure emphasizes the importance of the retention time to the storage volume since the spring 24 hour curve is below the summer 72 hour curve (opposite to Figure 5.8).

5.4.2 Infiltration Volumes

Figure 5.9 indicated that the storage volume required to infiltrate all summer storms with an allowable 4 overflows per summer was 10 mm/ha (20 mm/imperv. ha since the watershed is 50 % impervious). This criteria may be satisfactory for concerns such as downstream recreation, aesthetics, and fisheries health and maintenance, but may be too stringent for a concern such as baseflow augmentation.

Likewise, the volume of infiltration derived in Figure 5.9 may be considerably greater than that required to mitigate thermal enhancement.

The difference in target infiltration volumes for different concerns requires additional research. A water budget analysis would provide usual information concerning the existing meteorological/hydrological relationships as they would relate to future conditions. Likewise, knowledge of historical water levels and groundwater aquifer systems (shallow, deep, storage capacity) would provide a better understanding of how much infiltration is required to sustain groundwater levels and enhance/maintain baseflow conditions.

In addition, it should be recognized that an objective may be to enhance baseflow instead of maintaining baseflow. Improvement of baseflow increases the maximum potential productivity of a stream which increases its ability to assimilate nutrients and produce ancillary benefits such as watercress, fish, muskrats, etc. Therefore, an understanding of the objective of infiltration, along with an analysis of site specific and regional conditions, is essential to the determination of infiltration requirements.

A preliminary analysis was conducted to determine a regional target infiltration volume for the purpose of baseflow augmentation assuming that existing baseflow conditions were to be maintained.

5.4.3 Baseflow Augmentation

The minimum volume of water required for baseflow augmentation can be assumed equal to the volume of infiltration lost due to urbanization. Monthly average baseflow values were determined as part of the direct runoff analysis for the Black Creek gauge. The baseflow can be attributed to infiltration from the pervious areas of the watershed (50 % of the area). Therefore the baseflow was divided by the pervious area in the watershed to determine the target value of infiltration per hectare of impervious development (78 mm/ha/summer). This volume of infiltration would be required per hectare of new development to ensure that the existing baseflow conditions would be maintained.

In order to design an infiltration device that would accommodate approximately 78 mm/ha each summer, the intensity, duration, and sequence of summer runoff events must be analysed. It was assumed that the impervious area produced 100 % of the direct runoff from the watershed (the direct runoff was determined by subtracting the baseflows from the streamflow). This assumption is not entirely valid but serves as a reasonable preliminary approximation. The subtraction of desired baseflow infiltration (78 mm/ha) from the summer runoff volume produced by the impervious area gives the total volume of allowable overflows per summer (< = this volume of overflows will produce infiltration of 78 mm/ha). A continuous simulation can then be made to determine the design storage volume for infiltration which corresponds to the allowable summer overflow volume. This design storage value was determined to be 5 mm/ha (10 mm per impervious hectare). This volume is half that required for the control of summer events with 4 allowable overflows per season.

The drawback of this analysis is that the soil types were lumped together on a regional basis and an average infiltration target was obtained for the entire watershed. The implementation of an average infiltration target on a local site basis, or even a Master Drainage Plan basis, becomes complicated since many soils will be unsuitable for constructed infiltration techniques.

An individual site analysis (pre-development infiltration versus post-development infiltration) would account for the variance in desired infiltration volume based on site specific soil conditions. It would not be feasible, however, to expect that every consultant would be required to provide a continuous analysis to determine the required baseflow volume on a site by site basis.

An attempt was made to provide a crude analysis of the effect of different soil types on infiltration using the Soil Conservation Service (SCS) Curve Number (CN) method and a 25 mm two hour Chicago distribution storm. Table 5.1 indicates the specific soil types, hydrologic classification, and corresponding curve numbers that were used in the analysis. The SCS CN method only gives an indication of the rainfall abstraction (or rainfall losses). Part of the rainfall abstraction is infiltration which is dependent on the soil moisture condition. Antecedent Moisture Condition (AMC) II which is an assumed 'average' soil moisture condition was used in the analysis. Rainfall abstraction also includes initial abstractions such as depression storage, infiltration prior to the start of runoff, and interception. Therefore the analysis can only provide an approximate indication of the infiltration volume.

Figure 5.9 Stormwater Quality Storage Volumes

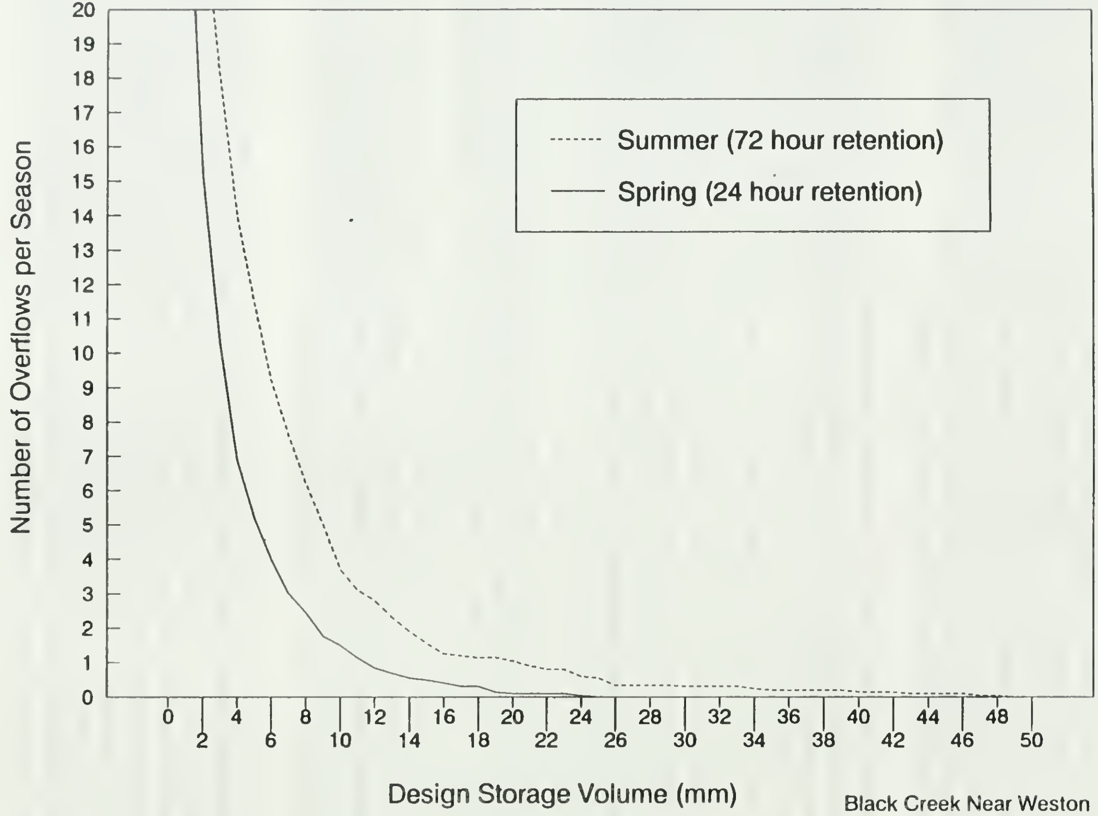


Table 5.1 Hydrologic Properties of Soil Types			
Soil Type	SCS Hydrologic Classification	Curve Number AMC II	Rainfall Abstraction (mm)
Sand	A	38	23.1
Sandy Loam	AB	43	22.9
Loam	B	65	20.8
Silt Loam	BC	71	19.9
Clay Loam	C	76	18.8
Clay	D	81	17.4

AMC II conditions represent an assumed 'average' soil moisture condition

Table 5.1 shows that for a 2 hour 25 mm storm there is not a wide variance for the rainfall abstraction with soil type based on the SCS CN method. This is emphasized by Figure 5.10. Figure 5.10 shows the desired infiltration volume required per hectare of site for different soil types (A, AB, B, BC, C, and D) and different levels of development intensity. Figure 5.10 was developed by adding the runoff from the impervious area (100 % runoff) to the natural runoff from the corresponding percentage of pervious area (Table 5.1) and then subtracting the runoff from the entire area in its natural pervious condition. The resulting value signified the target value of infiltration for the specific soil type and level of imperviousness. In the typical range of site imperviousness (50 % to 80 %) there was still a sizeable desired infiltration volume for silt-clay soils even though there was less infiltration in the pre-development situation.

<u>This baseflow analysis emphasizes that further research is required to circumvent site-specific problems related to target infiltration values. Table 5.1 indicates that current standard event modelling practices do not reflect the expected change in runoff with different soil types and thus, would not be appropriate.</u> The use of regional infiltration targets is beneficial but requires that the appropriate locations for infiltration be designated at the Master Drainage Plan level. Landowners who are located in the Master Drainage Plan area could contribute monies to the construction of appropriately sized infiltration facilities in pre-determined areas specified in the Master Drainage Plan. This would ensure that a landowner with suitable soils for infiltration would not be burdened with the entire Master Drainage Plan infiltration target and that landowners with unsuitable soils would still have some responsibility for baseflow augmentation. This approach would only be viable if the current method of piecemeal development was abandoned.

5.5 Hydrologic Design Summary

Continuous analysis is recommended for the estimation of BMP storage volumes. Continuous simulation has several advantages over precipitation design storms and design runoff events such as :

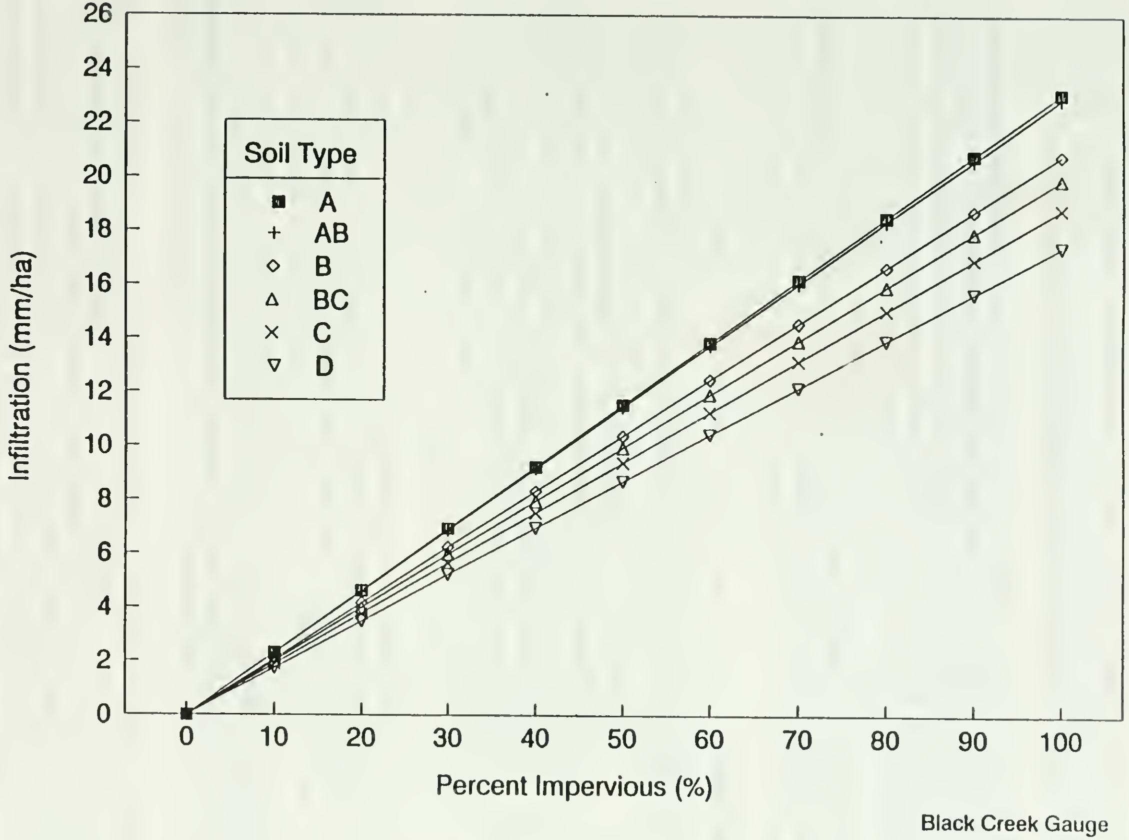
- snow accumulation and melt is considered (spring runoff timing)
- the entire volume of runoff is routed through the design storage
- consideration is given to the runoff timing related to retention time
- the relationship between precipitation and runoff is considered
- seasonal effects of runoff are considered (longer storms in the spring, more storms in the summer)
- continuous analysis results can be used to predict other essential watercourse characteristics (bedload movement and channel morphology responses).

The resulting runoff series should be analysed on a seasonal basis to determine the appropriate BMP storage value. A seasonal analysis should be performed since there are seasonal effects for both water quality concerns and BMPs themselves.

On a watershed, or large master drainage, scale continuous analysis could involve the use of relatively sophisticated models such as HSP-F. However, the term continuous analysis, not continuous simulation, was specifically used recognizing that there is the possibility of using simpler methods for regional or local water quality analyses. The results from a regional analysis could be easily extrapolated for use at a local level. In this sense, the local water quality BMP would still be designed based on some form of continuous analysis.

This simpler approach is presented to prevent the scenario where a consultant is burdened with running large water quality simulation models over extensive periods of time for each local 2 ha development.

Figure 5.10 Regional Infiltration Volumes



5.6 Relationship of Design Parameters to Agency Objectives

The choice of stormwater quality storage required for a particular water quality concern is based on a technical analysis of hydrologic conditions in the watershed. As such, there should not be any disagreement among reviewing agencies concerning the required storage volumes.

There will be differences, however, biased by the particular concerns of each agency, on how the volume should be implemented. For the most part, these conflicts will be addressed by the nature of the BMP selection process, since all water quality concerns must be addressed by the BMP, or combination of BMPs. Other conflicts should be resolved by reviewing them in the context of the water quality objectives determined through the Watershed and Master Drainage Planning.

The following sections will provide some insight on how some of the conflicting requirements from different agencies can be minimized or eliminated.

5.7 Design of Ponds

The criteria, and preferences, of the different reviewing agencies can be summarized as follows:

MOE -	pond should act as a sedimentation basin (top draw)
MNR -	pond should minimize thermal impacts (bottom draw), extended detention ponds may be more suitable
CA -	pond must provide peak flow and erosion control
MUN -	pond must provide peak flow control, wet ponds are a liability, maintenance must be addressed

Extended detention dry ponds satisfy most of the above concerns. They provide excellent sedimentation, prevent thermal enhancement from occurring due to lack of a permanent pool, should satisfy any erosion requirements depending on the design drawdown time, satisfy perceived liability concerns, and can incorporate storage above the extended detention storage to provide additional peak flow control.

There will be instances, however, when a wet pond is required, due to the enhanced pollutant removal capabilities afforded by aquatic vegetation and biological interactions in the pond. A wet pond may also be desired since it provides more opportunities for recreation and aesthetic enhancement of the site.

Several guidelines can be followed when designing wet ponds to satisfy all of the different concerns expressed by reviewing agencies. It should be stressed that this section provides a framework to relate agency objectives to pond design, but is not intended to define strict rules which dictate pond design. The evolution of BMP design will rely on innovative solutions to existing problems. Innovative solutions should be encouraged and recognized by reviewing agencies so that consultants will have the incentive to try new ideas instead of relying on "factory production" approvals. Consultants must design water

quality facilities based on their professional duty to provide the most cost-effective design which meets the downstream water quality objectives.

MOE - the pond should have a sedimentation forebay, which has a minimum length to width ratio of 5:1

MOE - minimum length to width ratio for the entire pond of 3:1

MNR - the majority of the pond should have a depth between 2-3 metres. If a sedimentation forebay is designed, the area next to the pond outlet could be made deeper (4-5 metres deep). A dual outlet (mixed water from top and bottom), or bottom draw outlet could be designed to release cooler water from the pond. If a pond is designed with a deep area of water, aeration should be considered in this section to prevent anaerobic conditions from occurring and negate the potential for discharge of anoxic water.

MNR - large length to width ratio for the pond will enhance opportunities for shading along the edge of the pond. Care must be taken to ensure that trees do not overhang the pond since the leaves will contribute organic loadings to the pond.

CA - the outlet can be designed to incorporate extended detention above the permanent pool. The release rate from the pond can be set according to erosion control guidelines. Currently the guideline is the control of the 2 year storm to pre-development levels. This guideline has been questioned and there are current initiatives by MTRCA to update the guidelines for erosion control.

MUN - The liability concerns can be satisfied by ensuring that there are 7:1 slopes around the pond. The safety can be further enhanced by providing a 3 m bench around the pond and planting rows of vegetation to stabilize the banks and act as a safety net to prevent people from falling into the pond. The inclusion of a sediment forebay will ease maintenance requirements. The sediment forebay can also be oversized to reduce the frequency of sediment removal to 15 or 20 years. Storage can be provided above the permanent pool to address peak flow control.

Table 5.2 provides a framework relating example design guidelines to agency objectives.

There are obvious conflicts in the guidelines presented in Table 5.2. For example, baseflow augmentation cannot be achieved by infiltration in areas which could contaminate regional groundwater resources. One solution to this problem would be to used extended detention which would more closely represent the slow release of baseflow into the stream.

A solution to the problem of thermal enhancement by a wet pond could be a top draw discharge into a radiator shaped pipe design buried in the soil.

Maintenance of a sediment forebay can be facilitated by the use of concrete slabs which allow openings for vegetative planting.

There will be trade-offs between innovation and standardization. Innovation will allow water quality designs to evolve, but threatens to lengthen approval times due to the evaluation of new designs.

Table 5.2 Framework Relating Example BMP Design Criteria to Agency Objectives

M.O.E.	M.N.R.	Conserv. Authority	Municipality
Pollutant Removal - sediment forebay - aquatic vegetation - 3:1 L/W ratio for ponds - 2-3 m average depth in ponds - use of infiltration Groundwater Protection - restricted use of infiltration	Warm Water Fish - 2 m average depth in ponds - min. 1 ha surface area for ponds Cold Water Fish - restricted use of wet ponds - bottom or dual draw (wet ponds) - underground pipe discharge for cooling purposes - use of infiltration Waterfowl - 50% of area with 1 m average depth (wet ponds) - tree setback (50 m - flightline) - use of shrubs and vegetation for habitat - use of shallow islands in pond centre Baseflow Augmentation - use of infiltration	Erosion Control - extended detention above permanent pool - use of vegetation in forebays to reduce pond velocities Flood Control - peak shaving storage above permanent pool - use of infiltration to reduce volume Conservation - habitat protection and enhancement - valleyland protection and enhancement - landforms - public access - recreation - heritage	Flood Control - peak shaving storage above permanent pool - use of infiltration to reduce volume Safety - min. 4:1 slopes around pond - 3 m bench around pond - use of vegetation to break falls Maintenance - use of sediment forebay - lining of forebay bottom with concrete mini-slabs

Note : the design guidelines in Table 5.2 are example criteria used by different agencies in different jurisdictions with similar objectives. As such, the numerical values may not reflect actual agency policy

Reviewing agencies must be willing to accept some degree of uncertainty regarding the performance of new designs, and must be willing to be flexible regarding guideline criteria due to site specific circumstances.

It must be stressed that the BMP design parameters are typical values based on U.S. agency standards and specifications. They are not "hard and fast" criteria which are currently adopted by Ontario agencies. Table 5.2 is presented to highlight the conflicts between the BMP design parameters, and hence, agency objectives. Conflicts which do, and will, arise must be resolved by either relaxing or compromising agency criteria, or by modifying traditional BMP designs (providing innovative solutions) to achieve all agency criteria. Reviewing agencies must encourage innovation, and at the same time, be willing to compromise on the performance level of their criteria.. If the reviewing agencies are inflexible regarding their criteria, approvals for water quality BMPs will become a lengthy, frustrating, and arduous task.

6.0 WATER QUALITY PONDS AND INTEGRATED BMP DESIGN

The most common structural BMP used in Ontario is the water quality pond. Most designs have concentrated on the basic sedimentation capabilities of the devices in attempting to address stormwater quality concerns. Ponds provide many other benefits and can be designed to provide environmental opportunities and enhanced water quality control. They are not however, an all-encompassing solution to stormwater concerns. As indicated in the previous chapters, a range of BMPs will often be necessary to address basin concerns. Ponds will generally form only one element in a comprehensive BMP solution, albeit often the most important element.

Because of the prevalence of ponds and their likely ongoing importance in BMP planning, the first portion of this chapter provides a review of the problems associated with them. This review leads to the conclusion that in most instances a pond alone will be insufficient to address all concerns. The remainder of the chapter is therefore devoted to two examples which illustrate the integrated BMP selection process in which a range of BMPs are examined to arrive at a comprehensive solution.

6.1 Environmental Impacts of Ponds

Ponds are likely to continue to be an important element in stormwater quality control. Their limitations need to be recognized however, and the special design considerations which often have to be addressed need to be noted. In some cases the problems associated with ponds can be overcome by design. It should be recognized however that ponds are not suited to some applications, especially where baseflow preservation or groundwater recharge are among the concerns driving the BMP plan. The following is a brief description of some of the problems associated with ponds. These problems often preclude the use of ponds as a single option BMP solution.

6.1.1 Thermal Impacts

One of the major drawbacks associated with wet ponds is thermal warming. Thermal enhancement occurs due to the relatively small size and depth (1-2 m) of a stormwater management pond. It is not unusual for the surface water of a stormwater management pond to reach temperatures of 24°C to 28°C (Gemza and Robinson, 1989) during the summer months (temperatures above 21°C are considered harmful to cold water fisheries (Schueler, 1987)). The Rouge River Watershed Management Plan identified river temperature as having the single largest influence on fish survival in the Rouge River (Marshall Macklin Monaghan Limited, 1989).

Deeper ponds (>3 m) have a greater buffering capacity against thermal enhancement but have the potential to become thermally stratified. Stratification occurs when a layer of warm water (due to light penetration) resides over a layer of colder, more dense water (no light penetration). Little or no interaction occurs between the two layers. Mixing due to lake circulation occurs in the upper layer but no mixing occurs in the lower layer, due to the difference in densities, which virtually becomes stagnant.

The density difference also negatively affects the settling characteristics of the pond. The bacteria (benthos) on the pond bottom continually oxidize plant material depleting the oxygen in the lower layer since there is no interaction with the oxygen rich upper layer (oxygen depletion usually occurs in all stormwater lakes due to aquatic species and plant respiration and plant decomposition, but is most prevalent in stratified ponds). The depletion of oxygen in the lower layer can become so severe that anaerobic conditions occur. Under anaerobic conditions stable pollutant compounds which had previously settled out reduce to more soluble forms (ie. in the case of iron, ferric reduces to ferrous). These contaminants, being in solution, would be available for consumption by plant and aquatic species. Gases are also created under anaerobic conditions since ammonia reduces to ammonium and sulphate reduces to hydrogen sulphide. These gases could create odour problems in the pond. In the fall the upper layer of water cools, due to the colder atmospheric conditions, until the density of the upper layer of water is greater than the lower layer. At this time, a fall turnover occurs, where the upper layer falls to the bottom of the pond displacing the lower layer. If the lower layer is anoxic (pollutants in solution), there is the potential for fish kills since this water would be toxic to fish species.

6.1.2 Baseflow Augmentation

Wet ponds are useful for peak flow control, sediment control, nutrient removal (with the addition of a marshland forebay or aquatic vegetation), and limited bacterial control. Wet ponds do not provide recharge of groundwater or baseflow augmentation since infiltration of stormwater is not provided. Volume control is not a characteristic of ponds.

The main objective of stormwater management in general is to maintain pre-development hydrologic conditions (pre-development refers to natural conditions not existing conditions ie. agriculture or current development). The addition of impervious development changes the hydrology of a watershed by shifting the runoff volume to surface runoff (as opposed to surface runoff, interflow, and groundwater), increasing peak flows (lower roughness of pipes and pavement compared to grass, and change of runoff regime to mostly surface runoff), decreasing summer baseflow (lack of groundwater recharge due to loss of infiltration) and concentrating flows in several areas (grading, pipe networks) which creates erosion. Wet ponds can be designed to mitigate peak flows and erosion, but usually do not provide baseflow augmentation due to the difficulty in simulating the response of interflow and groundwater from a pond outlet. The difficulty stems from the relative timeframe of hydrologic responses (surface water - minutes, hours, interflow - days, weeks, groundwater - months, years).

6.1.3 Nutrient Removal

Stormwater contains nutrients such as phosphorus and nitrogen. These nutrients are the result of excess fertilization of urban land, atmospheric deposition, and decaying plant and organic matter which get transported by the impervious areas and stormwater pipe system. The abundance of nutrients can produce eutrophic conditions triggering algae blooms and oxygen depletion during the algae decomposition. Although wet ponds provide some nutrient removal capabilities, they are limited to the removal of particulate nutrients through sedimentation. Typical removal rates for nutrients through sedimentation is

in the order of 50%. This is likely sufficient for control of the spring loading (basin export concerns), but may not be sufficient for summer-oriented in-stream nutrient control. Wet ponds cannot remove soluble forms of phosphorus and nitrogen without the addition of aquatic plants or wetland vegetation. Nutrient control in wet ponds can be enhanced by plantings of aquatic vegetation, either in a forebay or around the edges of the pond. Further improvements can be made by having a diverse "bug" and fish community since there is a "top-down" control of water quality exerted by the aquatic animal population is streams and wetlands.

The decomposition of aquatic vegetation depletes the amount of dissolved oxygen in the pond albeit at a time of reduced importance (fall). Depletion of oxygen levels can create anoxic conditions in the pond which are toxic to fish species. Research is needed to examine nutrient and heavy metal cycling in aquatic vegetation.

6.1.4 Environmental Surroundings Impact of Wet Ponds

Generally, wet ponds provide benefits to the immediate surrounding area such as wildlife and aquatic habitat, and a suitable environment for vegetation which acts as a food source for terrestrial and aquatic species. Wet ponds typically offer more opportunities for multi-use design than other BMPs.

Wet ponds can also have negative impacts on the surrounding environment. Wet ponds are generally large in size due to the need for a permanent pool of water in addition to storage requirements for influent stormwater. Construction of large wet ponds in the valleylands can destroy existing vegetation and wildlife habitat. In sensitive areas where existing resources are to be maintained, the land requirements for wet ponds can be prohibitive. This is particularly important in retro-fit situations where available land is often limited to parkland or flood plain areas. The use of ponds in such situations must be assessed on a site by site basis, weighing the benefits of water quality control against the loss of parkland or reduction in floodplain storage.

6.1.5 Remedial Measures for Wet Ponds

Certain remedial measures can be taken to offset some of the drawbacks associated with wet ponds.

a) Mitigation of Thermal Enhancement

The most common method for mitigating thermal enhancement is the use of bottom-draw. Ontario data indicate that for ponds up to 2 m deep, this is unlikely to be effective, because the ponds become completely mixed. Deeper wet ponds (>3 m) present problems since they have the potential to become thermally stratified. Stratified ponds avoid thermal problems but become anoxic more frequently than non-stratified ponds, and have non-ideal settling characteristics. For deep ponds dual outlets (surface + bottom) can be used since water at the bottom of the pond will be cooler than surface water. Dual or mixed outlets are preferred since water extracted from the

bottom of a pond can be depleted of oxygen (and potentially anoxic). Discharge design can be used to ensure rapid re-aeration of effluent.

The use of artificial aeration (ie. fountains) would allow the design of deeper ponds. Artificial aeration, which maintains circulation of the lower layer of water, can be used to overcome the problem of thermal stratification and oxygen depletion (anaerobic conditions). The use of aeration to overcome pond problems requires further research since the success rate of artificial aeration is inconsistent.

MNR is conducting research into thermal mitigation. Efforts are limited to in-stream applications but will examine such things as underground piping to cool discharge. Similar research in association with pond pilot projects is warranted. At present however, thermal impacts of ponds will usually be addressed through post discharge infiltration, vegetative plantings (shrubs and trees) to shade wet ponds or compensating efforts such as tree planting (for stream shading) downstream, in addition to the discharge design.

b) Baseflow Augmentation

Wet ponds are incompatible with baseflow augmentation due to the requirement for a permanent pool of water in a wet pond. Ponds are routinely lined with clay so that the pond will retain water. This prevents infiltration, and hence, baseflow augmentation, from occurring.

While various innovative designs may be possible, baseflow augmentation is not a function easily incorporated into a wet pond design. If baseflow is a concern, use of BMPs which promote infiltration should be considered, either singularly or in combination with a pond.

c) Nutrient Removal

As noted previously, aquatic, and aquatic fringe, vegetation can be used to enhance nutrient removal in a wet pond. Vegetation is required, since it provides uptake of soluble nutrients which cannot be removed by sedimentation.

Proliferation of aquatic plants and algae can lead to oxygen depletion and aesthetic problems within ponds. Chemical treatment or aeration can be used to control excessive plant or algal growth. Chemical treatment, such as copper sulphate, kills algae (which has consumed the nutrients) but leaves residuals which are toxic to aquatic species and should therefore be used with caution where downstream resources exist. Aeration discourages algae from forming by providing an undesirable environment for growth (algae grows much more rapidly under anoxic conditions), but does not remove any of the nutrients from the water.

d) Mitigation of Impact to Surrounding Environment

The size of the permanent pool in a wet pond is important with respect to the degree of pollutant removal. A larger wet pool provides a greater retention time and better pollutant removal (up to

a limit). Stormwater storage is provided in addition to the permanent pool volume. The permanent pool requires the wet pond to be larger than a corresponding dry pond, or extended detention dry pond. The larger size may require the destruction of a larger area of existing vegetation during its construction. Unfortunately, there are no easy solutions. The permanent pool should have a restriction on the maximum allowable depth since deep ponds are subject to temperature stratification during the summer. Temperature inversions promote anoxic conditions in the lower depths of the pond. Release of this water is potentially harmful to aquatic species downstream of the pond. Therefore, it must be recognized that there may have to be trade-offs between the destruction of existing vegetation and stormwater quality enhancement.

6.1.6 Conclusions Regarding Generalized Use of Wet Ponds

The generalized use of wet ponds for water quality enhancement would be desirable for several reasons:

- Dry ponds are a common and accepted form of stormwater quantity management. This familiarity would facilitate the implementation of stormwater quality wet ponds.

- Retrofit situations could be accommodated by the conversion of the existing network of dry ponds into wet ponds.

The use of wet ponds, however, can have negative impacts on the surrounding environment, as indicated by sections 6.1.1 - 6.1.4. Therefore, it would be inappropriate to adopt guidelines which endorsed the singular use of wet ponds for stormwater quality mitigation. Concerns regarding the downstream water uses must dictate stormwater quality controls. This ensures the efficient use of money and resources for environmental protection. Ponds will often be a part of the BMP solution, but at a minimum will be supplemented by various site control efforts which seek to promote local lot infiltration (eg roofs discharging to lawns) and utilize vegetative practices.

6.2 Examples of Integrated BMP Design

The following sections demonstrate the application of the BMP selection process outlined in Section 3 and 4 of this report. The case problem presented in the BMP workshop was used as the first development scenario and is an example of a relatively unconstrained situation. The second development scenario was based on an actual proposed development and represents an example of a situation with specific constraints. In each case it has been assumed that the BMP design is being undertaken within the context of a master drainage plan which included certain regional BMPs.

In the following examples Figure 5.9 has been used to determine the storage requirements for BMPs. This figure was developed through an analysis of the Black Creek watershed. It should be recognized that a similar figure should be generated for the subject watershed, whenever sufficient data is available.

The storage volume designed to deal with summer water quality concerns was determined using the summer curve (72 hours retention). The storage required for spring water quality concerns was based on the spring curve (24 hours retention). It was assumed that 4 overflows per season were allowable in the summer, and that no overflows were allowed in the spring. No overflows were allowed in the spring since the events occur over long durations and represent a significant percentage of the annual runoff volume and suspended solids loadings.

6.2.1 Workshop Development Scenario

A 125 ha condominium development was proposed adjacent to a cold water stream. The development bordered 2 km of the stream which was provided with a 10-15 metre buffer strip with good shading.

The overall imperviousness of the development was estimated at 25%. The soils of the site provided good drainage.

The site was located near the headwaters of the stream. The area upstream of the site was 300 ha, 50% of which was used for agricultural purposes, and 50% of which was forested.

It was assumed that a Master Drainage Plan (MDP) was prepared for this stream, but that there was no Watershed plan. The Master Drainage Plan identified the following basin, instream, and local water quality concerns :

- sediment accumulation (concern type-basin, seasonality-spring)
- bioaccumulation (concern type-basin, seasonality-none)
- nutrient loading (concern type-instream, seasonality-spring)
- fisheries maintenance (concern type-instream, seasonality-spring to fall)
- fisheries movement (concern type-instream, seasonality-none)
- baseflow preservation (concern type-instream, seasonality-summer)
- aquatic food source protection (concern type-instream, seasonality-spring to fall)

- preservation of riparian habitat (concern type-local, seasonality-none)

It was assumed that concern about groundwater contamination was negligible, in terms of human consumption. It was also assumed that quantity control for flood protection would be provided by regional facilities. The MDP set the following performance criteria for local BMP plans:

- 24 hr storage should be achieved for spring runoff to promote settling of particles down to a 40 μ size during the major loading period
- 72 hr storage should be achieved for summer runoff with the provision that post development infiltration volumes should match pre-development infiltration volumes
- a 15 m riparian buffer strip should be maintained along all stream channels to prevent thermal degradation and provide a corridor of terrestrial habitat

Integrated BMP Design Process

The following process (as described in Section 4) was followed during BMP selection :

1. Establish Basis for BMP Plan

   a. Re-evaluate local problems/concerns
   b. Prioritize basin, instream, and local concerns
   c. Select BMPs which satisfy basin concerns
   d. Select BMPs which satisfy instream concerns
   e. Select BMPs which satisfy local concerns

2. Identify Probable Design Characteristics of BMPs

   a. Eliminate BMPs which irreversibly violate established concerns

3. Screen BMPs Based on Site Characteristics

   a. Eliminate BMPs which violate physical site conditions
   b. Prioritize remaining BMPs based on land use constraints

4. Assess Opportunities Presented by Different BMPs

5. Select BMPs

   a. Identify BMPs or groups of BMPs for pre-design calculations
   b. Identify Capital and O & M costs for selected BMP solutions
   c. Select BMP solution based on a comparison of BMP costs, level of protection provided by the BMP solution, and opportunities provided by the solution.
   d. Identify any problems which must be addressed outside of the BMP design

1. Establish the basis for the BMP Plan

Specific performance criteria for the local BMP plan is available from the MDP. Although the basin and instream concerns were detailed in the Master Drainage Plan, all of the site specific local concerns or constraints may not have been fully identified. It is imperative that local concerns be re-assessed during the site stormwater management plan to ensure that BMP solutions are compatible with site specific problems/constraints, as well as the basin and instream concerns.

1a) Re-evaluate Local Problems/Concerns

It was assumed that aesthetics would be a concern due to the nature of the development (residential). Concerns associated with BMP aesthetics include algae, murky water, safety, odour, and mosquitoes. Further, because of the nature of the site (large portion of open space) it was assumed that the BMP plan should seek to maximize the creation of varied open space (open grassed areas, natural treed areas, water) as an amenity to the development. Natural areas and stream shading are addressed by the requirement for a 15 m buffer strip adjacent to the stream, as required by the MDP. The remaining local concerns should be addressed as part of the analysis of opportunities.

b) Prioritize basin, instream, and local concerns

The finalized set of concerns was prioritized into the following order in consultation with the regulatory agencies:

Problem/Concern	Seasonality	Parameters
1. Fisheries Maintenance	Spring to Fall	SS, flow, temperature, D.O.
2. Fisheries Movement	None	stream continuity
3. Nutrient Loading	Spring	P, K, metals
4. Sediment Accumulation	Spring	SS
5. Baseflow Preservation	Summer	low flow volume
6. Bioaccumulation	No seasonality	metals
7. Aesthetics	Summer	Nutrients, SS, safety

The protection of aquatic food sources, channel bank erosion stability, and the maintenance of riparian habitat was assumed to be adequately addressed by the MDP requirement for a 15 m buffer strip along the stream channel (although in reality, this would have to be reviewed in detail).

c) **Select BMPs which Satisfy Basin Concerns**

Sediment Accumulation -	Extended Detention Ponds Wet Ponds Storage Tanks Water Quality Inlets Filter Strips Grassed Swales
Bioaccumulation -	Infiltration Trenches Infiltration Basins Porous Pavement Extended Detention Ponds Wet Ponds Filter Strips Wetlands Seepage Trenches

d) **Select BMPs which Satisfy Instream Concerns**

Fisheries Maintenance -	Infiltration Trenches Infiltration Basins Porous Pavement Filter Strips Grassed Swales Buffer Strips Seepage Trenches
Fisheries Movement -	same as Fisheries Maintenance off-line BMPs only
Nutrient Loading -	Vegetative Practices in Ponds Infiltration Trenches Infiltration Basins Porous Pavement Filter Strips Seepage Trenches
Baseflow Preservation -	Infiltration Trenches Infiltration Basins Porous Pavement Filter Strips Grassed Swales Seepage Trenches

e) Select BMPs which satisfy local concerns

Aesthetics -

- Wet Ponds
- Buffer Strips
- Infiltration Trenches
- Porous Pavement
- Water Quality Inlets
- Grassed Swales
- Filter Strips
- Seepage Trenches

Conclusions on Basis for the BMP Plan

The development of a local BMP plan will be relatively unconstrained because of the fact that quantity control is provided by regional facilities and a broad range of BMPs may be employed to address the various concerns. At this stage a large number of possible combinations seem possible. It is evident however, that because of the importance of in-stream fisheries concerns that infiltration will be a major part of the plan. Because of the requirement for retention of the spring load however, storage facilities are likely to be needed. A multi-facility design will be required, primarily because of the extensive range of water use concerns.

2. Identify Probable Design Characteristics of BMPs

2a) Eliminate BMPs which Violate Established Concerns

This task can be divided into two steps :

- eliminate BMPs which irreversibly violate established concerns
- limit the use of single BMP solutions which violate a major established concern

Elimination of BMPs which Irrevocably Violate Established Concerns

None of the BMPs irrevocably violate established concerns, with the exception that BMPs cannot be located on-line because of concerns regarding fish movement and food supply transmission.

Limitations of Single BMP solutions

BMP	Reason for Single Solution limitation
Wet Pond & Ext. Det. Wet Pond	Thermal Impact, Limited Nutrient Removal, Lack of Baseflow Preservation
Extended Detention Dry Pond	Limited Nutrient Removal, Aesthetics, Lack of Baseflow Preservation
Wetlands	Thermal Warming
Water Quality Inlets	Lack of Nutrient Removal, Lack of Baseflow Preservation
Infiltration Trench	Spring Loading Concerns
Infiltration Basin	Spring Loading Concerns
Porous Pavement	Spring Loading Concerns
Buffer Strip	Spring Loading Concerns
Grassed Swale	Spring Loading Concerns
Filter Strip	Spring Loading Concerns
Seepage Trench	Spring Loading Concerns

Conclusion

Surface infiltration devices (infiltration basins) cannot be employed to address spring loading because of concerns regarding frozen ground conditions. Structural surface infiltration trenches should be located below other treatment devices, designed for spring conditions, in order to prevent premature clogging. Subsurface infiltration trenches will also require a pretreatment device of some kind. In general, this precludes their use for a spring load design because of the size of the pretreatment facility that would be required.

Surface and subsurface storage devices may be employed to address spring loading concerns. Because of fisheries concerns special provisions will be required for surface storage devices to control thermal impacts. Storage devices cannot address the baseflow requirements.

A combination of storage and infiltration devices will be required to address the complete range of concerns.

3. Screen BMPs based on Site Characteristics

a) Eliminate BMPs which Violate Physical Site Conditions

The site conditions are made up entirely of well drained soils. This condition will render the creation of an artificial wetland very difficult as a stand alone option. Wetland characteristics may be consider as part of the design features of a wet pond. All other BMP types are physically feasible.

b) Prioritize remaining BMPs based on land use constraints

Since the proposed development provides a large green space (94 ha), virtually any combination of BMPs could be integrated into the site plan.

The size of the site is large in comparison to the typical area served by subsurface infiltration BMPs (see Figure 4.7). The typical area served is based primarily on the fact that other BMPs are more cost effective or practical for larger sites. For example, it is possible to design a distributed system of infiltration trenches but this would mean a more onerous maintenance requirement as well as higher construction costs compared to a single infiltration basin.

The vegetative options are not normally used as primary BMP on sites this size because of their limited effectiveness (compared to structural BMPs) and a greater vulnerability to natural drainage processes such as micro-channel formation and scour. As indicated in Section 4, it has been suggested as a general rule of thumb that the volume of runoff treated by vegetative BMPs alone should not exceed the ratio of pre development imperviousness to post development imperviousness. This effectively precludes the use of vegetative BMPs alone. Vegetative BMPs should be encouraged as a supplement to other BMPs as they may reduce storage requirements of structural BMPs. On this particular site, the significant areas of open space and the requirement to maintain a 15 m buffer strip along the stream will provide a system of vegetative BMPs.

Subsurface storage devices such as storage tanks and water quality inlets are not normally employed on large sites with significant open space because of the size of the facilities required and the high capital cost (compared to surface storage devices).

Based on the these considerations the potential BMPs are prioritized as follows:

Wet Pond
Extended Detention Dry Pond
Infiltration Basin
Infiltration Trench
Porous Pavement
Seepage Trenches
Storage Tank
Grassed Swales
Filter Strip

Buffer strips were not included in the priorization since they were a mandatory requirement and not an option. It should be noted that the priorization involves a subjective analysis on the part of the BMP designer. Although the prioritized list will vary based on past experience with different BMP types, the selection process will ensure that all of the watershed/tributary concerns are addressed and that other major items such as safety, aesthetics, recreation, and cost are reviewed before the final selection of a BMP(s) is made.

4. Assess Opportunities Presented by Different BMPs

BMPs may be eliminated from further consideration if they are redundant. In order to be classified as redundant, the following conditions must be met:

- elimination of the BMP cannot result in a use concern not being addressed
- the BMP does not offer opportunities which could not be pursued in conjunction with other BMPs

Based on the characteristics of wet ponds and extended detention dry ponds, the requirements for both spring and summer runoff control can be addressed. Each would be weak in nutrient removal, but the wet pond would provide greater scope for aquatic vegetation to enhance nutrient removal.

Both pond types would have to be designed to minimize thermal impacts. So long as the selected facility is sited off-line, neither would present problems in regard to fisheries movement or food source protection. **Neither type of facility will address concerns related to baseflow preservation however.** Some form of infiltration oriented BMP must be utilized to address this concern.

The following are a listing of potential opportunities associated with the BMPs:

Wet Pond	erosion control, habitat (aquatic and wildlife), landscape amenity, recreational amenity, aesthetic enhancement
Extended Detention Pond	erosion control, habitat (limited aquatic, wildlife), recreational amenity
Infiltration Basin	**low flow maintenance, no thermal impact, no concern for public safety,** aesthetics only moderately acceptable
Infiltration Trench	**low flow maintenance, no thermal impact, no concern for public safety,** aesthetically acceptable
Porous Pavement	**low flow maintenance, no thermal impact, no concern for public safety,** aesthetically acceptable
Seepage Trenches	**low flow maintenance, no thermal impact, no concern for public safety,** aesthetically acceptable
Storage Tank	erosion control, **no thermal impact, no concern for public safety**
Grassed Swales	**no thermal impact, no public safety concern,** aesthetic problems (trash)
Filter Strip	habitat (wildlife), **no thermal impact, no public safety concern,** aesthetically acceptable

Buffer Strip	limited erosion control, habitat (wildlife), thermal reduction (shading), no public safety concern, landscape amenity, aesthetic amenity

NOTE: opportunities in bold print are those which offer additional potential improvements over the wet pond and extended detention pond.

The major opportunities presented by BMPs other than wet and extended detention dry ponds are related to baseflow maintenance and reduction of thermal impacts. Each of the infiltration BMPs provide these opportunities. Public safety concerns related to the wet pond will not be eliminated by use of any of the BMPs except the storage tank. The opportunities presented by the surface pond BMPs are deemed more important than the public safety concerns associated with these facilities, so long as attention is paid to safety considerations during design.

On the basis of the above, it was decided to formulate a BMP scenario using the following BMPs:

Wet Pond, Extended Detention Pond

Infiltration Trench or Basin, Porous Pavement

Buffer Strip (required by MDP)

These may be supplemented by grassed swales, filter strips, and seepage trenches at the detailed design stage. Vegetative practices in ponds will be considered to enhance nutrient removal and provide habitat diversity. The storage tank was eliminated from further consideration based on its redundancy.

5. Select BMPs

a) Identify BMPs or groups of BMPs for pre-design calculations

The following table was formulated to assist in scenario development and to ensure that all use concerns were addressed by the selected combination of BMPs.

Table 6.1 BMP Selection Chart (Example)							
Type of BMP	1	2	3	4	5	6	Sum
Wet Pond	X	X	D	D		X	3
Extended Detention Dry Pond	X	X	D	D			2
Vegetative Practices (Ponds)				X		X	2
Buffer Strip (required by MDP)	S		X			X	2
Infiltration Trench		X	X	X	X	X	5
Infiltration Basin		X	X	X	X	D	4
Porous Pavement		X	X	X	X	X	5
Grassed Swale	S		S		S	X	1
Filter Strip	S	S	S	S	S	X	1
Buffer Strip (optional)	S		S			X	1
Seepage Trench		S	S	S	S	X	1

1 Sediment Accumulation (Spring)
2 Bioaccumulation
3 Fisheries Maintenance
4 Nutrient Loading
5 Baseflow Preservation
6 Aesthetics
X BMP addresses the concern
D Special design considerations
S Supplementary use recommended

The nature of the concerns for this example is such that the BMP plan will require some form of storage device in order to address spring loading concerns (sediment accumulation and bioaccumulation). Infiltration techniques are deemed inappropriate for spring loading control because of performance concerns related to frozen ground or high sediment load. Some in-stream concerns (fisheries maintenance, nutrient loading) can also be addressed by storage facilities, although special designs may be required to address thermal effects, dissolved oxygen and enhanced nutrient removal. Concerns for fisheries maintenance and nutrient removal could be alternately be addressed with infiltration techniques. Baseflow preservation requires some form of infiltration technique. Although baseflow was rated fifth out of seven concerns in defining the priorities of the BMP plan, there are no conflicts which require that a choice be

made as to whether to pursue this objective. Techniques which address this concern must therefore be incorporated into the BMP plan.

Based on the above, several scenarios are possible, all utilizing a combination of storage and infiltration techniques, operated either in series or in parallel. The configuration of the final system will have cost implications, but at this stage the selection of the component BMPs will be based primarily on gross costs (capital and O&M). Cost refinement would be undertaken during detailed design of the facilities as part of the site design.

b) Identify Capital and O & M costs for selected BMP solutions

In order to cost the BMPs they must be sized. An analysis of the Black Creek watershed with the Bloor St. precipitation gauge produced the following target runoff volumes for the 125 ha area :

Spring runoff	-	15,625 m^3 (24 hour detention with no overflows/season)
Summer runoff	-	3,125 m^3 (72 hour detention for baseflow augmentation only)

The costing of BMPs can be dealt with at two stages since the infiltration devices accommodate the summer concerns while the ponds accommodate the spring concerns. In each case, the selection is between BMPs which present alternate means of addressing a subset of concerns. The buffer strip required by the MDP will not be costed as it is intended to leave the riparian buffer in its natural state.

The costing was calculated as a present value for 100 years of operation and maintenance with an average interest rate of 8 %. The present value cost includes the estimated cost of replacement, and thus, BMP service life.

Infiltration Facilities

Exfiltration

The summer runoff volume can be down-sized based on some of the influent stormwater infiltrating during the storm itself. The percolation rate of the soil was assumed to be that of a sandy loam :

Percolation rate = 5 min/cm

The amount of percolation was based on an exfiltration area of 3910 m^2 (2 metre trench depth), a porosity of 0.15 for the soil/filter bed, and a storm duration of 4 hours (4 hour Chicago). The exfiltration over 4 hours was calculated to be approximately 280 m^3. Therefore, the infiltration devices were sized to provide a storage volume of 2845 m^3.

Pre-Treatment

Pre-treatment of runoff was not costed during the initial selection process. It is recognized that pre-treatment would be required for all of the infiltration devices, and therefore, would not be the deciding factor in selection. Once the BMP plan was formulated, there would be another iteration of costing to ensure the optimum allocation of storage volume and pre-treatment volume. This would be necessary since the spring control BMP could provide pre-treatment to the summer BMP if the two were acting in series.

Land Costs

In this particular scenario land costs are not relevant due to the large green space areas available in the development plan. In most development plans this would not be the case, and land costs would have to be calculated. Determination of the value assigned to unit land costs can be complex. Wet ponds for instance will not allow secondary uses, beyond recreation, and will not typically be included in the parkland allotment. If designed as an amenity however, the wet pond facility may increase the value of fronting lots. In contrast, sub-surface infiltration BMPs often allow secondary uses (eg park dedication) but have no amenity value. Decisions on how to account for land costs will be development specific and should be determined in consultation with the owner.

Porous Pavement

Specifications :

Area	3910 m^2
Pavement Thickness	0.15 m
Gravel Depth	1.8 m at $n=0.4$
Sand Filter Depth	0.2 m at $n=0.15$

Table 6.2 Porous Pavement Capital Costs			
Material	Amount	Unit Cost	Cost
Pavement	3910 m^2	$ 15/m^2	$ 58,650
Pervious Pipes	21 pipes 63 m long	$ 15/m	$ 19,845
Sand Filter	782 m^3	$ 40/m^3	$ 31,280
Gravel Storage	7038 m^3	$ 40/m^3 *	$ 281,520
Excavation	7820 m^3	$ 10/m^3	$ 78,200
Overflow Pipe	63 m	$ 200/m	$ 12,600
Signs	3	$ 200	$ 600
Observation wells	2 m	$ 150/m	$ 300
Total Capital Cost			$ 482,995

* typical diameter = 25 mm

Table 6.3 Porous Pavement Maintenance			
Maintenance	Interval	Unit Cost	Total Cost
Vacuum and hose	4 x per year	$ 1325	$ 5,300 per year
Replacement	15 years	$ 482,995	$ 482,995 / 15 years

The total cost of the porous pavement based on a 100 year present value would be $ 773,460.

Infiltration Trench

Specifications :

Area	3910 m^2
Pipe Cover	1.2 m
Gravel Depth	1.8 m at n=0.4
Sand Filter Depth	0.2 m at n=0.15

Table 6.4 Infiltration Trench Capital Costs			
Material	**Amount**	**Unit Cost**	**Cost**
Filter Cloth	3910 m^2	\$ 10/m^2	\$ 39,100
Pervious Pipes	21 pipes 63 m long	\$ 15/m	\$ 19,845
Sand Filter	782 m^3	\$ 40/m^3	\$ 31,280
Gravel Storage	7038 m^3	\$ 40/m^3 *	\$ 281,520
Excavation	12512 m^3	\$ 10/m^3	\$ 125,120
Overflow Pipe	63 m	\$ 200/m	\$ 12,600
Seed and Topsoil	3910 m^2	\$ 2.50/m^2	\$ 9,775
Observation wells	2 m	\$ 150/m	\$ 300
Total Capital Cost			\$ 519,540

* typical diameter = 25 mm

Table 6.5 Infiltration Trench Maintenance			
Maintenance	**Interval**	**Unit Cost**	**Total Cost**
Grass Cutting	12 x per year	\$ .025/m^2	\$ 1,173 per year
Replacement	15 years	\$ 519,540	\$ 519,540 / 15 years

The total cost of the infiltration trench based on a 100 year present value would be <u>\$ 775,415</u>.

<u>Infiltration Basin</u>

Specifications :

Area	3910 m^2
Basin Depth	.75 m

Table 6.6 Infiltration Basin Capital Costs			
Material	**Amount**	**Unit Cost**	**Cost**
Rip Rap (Inlet/Spill.)	100 m^2	\$ 50/m^2 *	\$ 5,000
Pervious Pipes	21 pipes 63 m long	\$ 15/m	\$ 19,845
Excavation	2935 m^3	\$ 10/m^3	\$ 29,350
Seed and Topsoil	3910 m^2	\$ 2.50/m^2	\$ 9,775
Total Capital Cost			\$ 63,970

* nominal depth = 450 mm

Table 6.7 Infiltration Basin Maintenance			
Maintenance	**Interval**	**Unit Cost**	**Total Cost**
Grass Cutting	12 x per year	\$ .025/m^2	\$ 1,173 per year
Tilling (Disc)	Annual	\$ 400	\$ 400 per year
Litter Removal	Annual	\$ 0.20/m^2	\$ 782 per year
Re-vegetation	Annual	\$ 2/m^2	\$ 7,820 per year
Sediment Removal *	5 years	\$ 50/m^3 + labour	\$ 3,475 / 5 years

* Extra sediment removal required since pre-treatment facility not 100 % effective
Does not include transportation cost of sediment disposal
Assumed 25 m^3 of sediment per year handled by the pre-treatment facility which is 70 % effective

The total cost of the infiltration basin based on a 100 year present value would be \$ 198,520.

Wet Pond

Specifications :

Permanent Pool	15,625 m^3
Pool Depth	2 m
Storage Depth	1 m
Storage Volume	15,625 m^3

Table 6.8 Wet Pond Capital Costs			
Material	Amount	Unit Cost	Cost
Rip Rap (Inlet/Spill.)	200 m^2	\$ 50/m^2 *	\$ 10,000
Riser	1	\$ 6000	\$ 6,000
Excavation	31250 m^3	\$ 10/m^3	\$ 312,500
Vegetation (Aquatic)	3130 m^2 (10 m)	\$ .50/m^2	\$ 1,565
Outlet Pipe	20 m (450 mm)	\$ 200/m	\$ 4,000
Vegetation (Upland)	8,860 m^2 (20 m)	\$2.00/m^2	\$ 17,720
Total Capital Cost			\$ 351,785

* nominal depth = 450 mm

Table 6.9 Wet Pond Maintenance			
Maintenance	Interval	Unit Cost	Total Cost
Grass Cutting	12 x per year	\$ .025/m^2	\$ 2,658 per year
Litter (Aquatic)	Annual	\$ .20/m^2	\$ 1,560 per year
Weed Control (Upland)	Annual	\$ 0.10/m^2	\$ 1,325 per year
Planting (Upland)	5 years	\$ 0.10/m^2	\$ 1,560 / 5 years
Sediment Removal	10 years	\$ 65/m^3 + labour	\$ 20,250 / 10 years

The total cost of the wet pond based on a 100 year present value would be <u>\$ 441,755</u>.

<u>Extended Detention Dry Pond</u>

Specifications :

Storage Depth	2 m
Storage Volume	15,625 m^3

Table 6.10 Extended Detention Dry Pond Capital Costs			
Material	Amount	Unit Cost	Cost
Rip Rap (Inlet/Spill.)	200 m^2	\$ 50/m^2 *	\$ 10,000
Extended Detention Pipe	1	\$ 3200	\$ 3,200
Low flow channel	220 m	\$ 50/m	\$ 11,000
Outlet Pipe	25 m (450 mm)	\$ 200/m	\$ 5,000
Riser	1	\$ 6000	\$ 6,000
Excavation	15625 m^3	\$ 10/m^3	\$ 156,250
Vegetation (Aquatic)	3130 m^2 (10 m)	\$ .50/m^2	\$ 1,565
Vegetation (Upland)	6260 m^2 (20 m)	\$2.00/m^2	\$ 12,520
Total Capital Cost			\$ 205,535

* nominal depth = 450 mm

Table 6.11 Extended Detention Dry Pond Maintenance			
Maintenance	Interval	Unit Cost	Total Cost
Grass Cutting	12 x per year	\$ .025/m^2	\$ 1,870 per year
Weed Control (Upland)	Annual	\$ 0.10/m^2	\$ 800 per year
Planting (Upland)	5 years	\$ 0.10/m^2	\$ 800 / 5 years
Sediment Removal	10 years	\$50/m^3 + labour	\$ 14,100 / 10 years

The total cost of the extended detention dry pond based on a 100 year present value would be <u>\$ 252,710</u>.

c) Select BMP solution based on a comparison of BMP costs, level of protection provided by the BMP solution, and opportunities provided by the solution.

BMP	Capital Cost	O&M Cost	Total Cost
Infiltration Trench	$ 519,540	255,875	$ 775,415
Infiltration Basin	$ 63,970	134,550	$ 198,250
Porous Pavement	$ 482,995	290,465	$ 773,460
Wet Pond	$ 351,785	89,970	$ 441,755
Ext. Detention Dry Pond	$ 205,535	47,175	$ 252,710

Note: all costs are present values, over a 100 year period, assuming a typical replacement interval.

Based solely on cost, the BMP solution would combine an extended detention dry pond with an infiltration basin.

Opportunities

Infiltration Trench	Recreation
Infiltration Basin	Wildlife habitat
Porous Pavement	Saves developable land, hazard reduction
Wet Pond	Wildlife and aquatic habitat, recreation, landscape amenity
Extended Detention Dry Pond	Wildlife habitat

For the infiltration facilities, the opportunities provided by the more expensive BMPs (trench and pavement) are of little extra benefit because of the large amount of open space available. With respect to the ponds, the wet pond offers significantly greater opportunities for a variety of amenities which will enhance the development.

Level of Protection

The wet pond should produce better nutrient removal than the extended detention dry pond due to the environment for aquatic vegetation. The extended detention dry pond would be less susceptible to thermal enhancement than the wet pond.

Selection

Wet Pond and Infiltration Basin were selected due to the relative costs and ancillary benefits from a wet pond compared to an extended detention dry pond. It is anticipated that a final design will configure these BMPs in series, with the wet pond discharging into the infiltration basin. This configuration will allow use of the wet pond as a pre treatment device for the infiltration basin. Concerns regarding thermal

impacts and nutrient removal for the wet pond will be addressed by subsequent discharge to the infiltration facility.

d) Identify any problems which must be addressed outside of the BMP design

All use concerns are addressed by the BMP plan. There is therefore no need to consider "soft" BMPs such as zoning. Guidelines should be established with respect to fertilizer and pesticide application on communal lands because of the large open space areas.

6.2.2 Actual Development Scenario

A 0.9 ha condominium development was proposed adjacent to Lake Ontario. The undertaking involved the redevelopment of an older commercial neighbourhood along the lakefront.

The overall imperviousness of the development was estimated at 40 %. The soils on the site were a combination of natural soils and lake fill. A soils engineer was retained to perform borehole testing of the soils on the site. The drainage classification of the soils was variable since the initial soils testing indicated different proportions of sand, silt, clay, and rubble at different locations. Most of the test pits revealed traces or seams of clay indicating that the feasibility of full-exfiltration infiltration techniques was questionable.

An environmental study report was completed as part of the overall redevelopment plan. The environmental quality plan for the waterfront area recommended the implementation of a regional water quality wetland to accommodate stormwater drainage from all of the developments. The wetland would be designed with a sedimentation pond for the pre-treatment of runoff. While the wetland concept received support from the regulatory agencies, it was recognized that it represented a relatively untested technology within the Ontario context. It was therefore determined that the wetland should be the final element of an overall stormwater control strategy. On-site controls were to be pursued to a reasonable extent and infiltration was to be utilized to the maximum extent feasible. In effect, a "multiple barrier" approach to water quality was to be taken.

Stormwater quantity (peak flow) control was determined not to be a concern due to the proximity of the development to Lake Ontario. On-site control of the volume of stormwater was noted as a criteria for all new developments in this area.

The following concerns were determined based on the water quality plan.

Table 6.12 Listing of Stormwater Quality Concerns				
Problem	Concern	Season	On-site	Regional
Basin Loadings	Nutrients	Spring		X
Contaminant Accumulation	Nutrients, metals, organics	Spring		X
Aquatic Bioaccumulation	Metals, organics	None		X
Sediment Accumulation	Suspended solids	Spring		X
Fishery Health	Temperature Suspended solids	Summer Summer	X X	 X
Recreation	Bacteria	Summer	X	X
Stormwater Volume	Wetlands Sizing	None	X	

1. Establish the basis for the BMP Plan

The environmental quality plan identified both bacterial and pollutant concerns. When the wetland was completed it was expected that long retention times would be available. It was questionable whether the wetland would proceed immediately, however, and so on-site controls had to consider recreational criteria.

The criteria which was selected required the control of all summer storms with 4 allowable overflows per summer.

a) Re-evaluate Local Problems/Concerns

The aesthetic impact of the on-site BMP solution was identified as an important local concern. The development bordered on a waterfront park/boardwalk which was intended to be a focal point for public recreation in the waterfront area. Possible concerns associated with BMP aesthetics included algae, murky water, safety, odour, and mosquitoes.

Other local concerns included the variability of soils and their natural exfiltration capability.

b) Prioritize basin, instream, and local concerns

It had been previously decided that long term basin concerns (basin loadings, contaminant accumulation in sediment and bioaccumulation) would be addressed primarily through the wetland system, serving the

full area. The remaining concerns which were to be addressed at the site level were prioritized as follows:

Problem/Concern	Seasonality	Parameters
1. Wetland Sizing	Spring to Fall	Volume of stormwater
2. Aesthetics	Summer	Nutrients, SS, safety
3. Recreation	Summer	Bacteria
4. Fisheries Maintenance	Spring to Fall	SS, flow, temperature, D.O.

All concerns were either of a local or basin nature, as there are no natural watercourses in the area.

c) Select BMPs which Satisfy Concerns

Wetland Sizing -	Infiltration techniques Soft BMP techniques (green space)
Nutrient Loading -	Vegetative Practices in Ponds Infiltration Trenches Infiltration Basins Porous Pavement Filter Strips Seepage Trenches
Thermal Mitigation -	Infiltration Trenches Infiltration Basins Porous Pavement Filter Strips Grassed Swales Seepage Trenches
Recreation -	Infiltration techniques Ultra-violet disinfection Ozonation
Aesthetics -	Wet Ponds Infiltration Trenches Porous Pavement Grassed Swales Buffer Strips Filter Strips Water Quality Inlets/Tanks

2. Identify Probable Design Characteristics of BMPs

The long list of potential BMPs was examined to identify conflicts, determine preliminary combinations of BMPs and establish special design considerations for specific BMPs.

a) Eliminate BMPs which Violate Established Concerns

This task can be divided into two steps :

- eliminate BMPs which irreversibly violate established concerns
- eliminate the use of single BMP solutions which violate a major established concern

Elimination of BMPs which Irrevocably Violate Established Concerns

None of the BMPs irrevocably violate established concerns. This is largely due to the fact that there are no "in-stream" concerns and that ultimate discharge will either be routed to groundwater or through the wetland facility.

Elimination of Single BMP solutions

Some BMPs will not be appropriate as a "stand-alone" solution:

BMP	Reason for Single Solution Elimination
Wet Pond & Ext. Det. Wet Pond	Thermal Impact, No Reduction in Volume
Extended Detention Dry Pond	Aesthetics, No Reduction in Volume
Wetlands	Thermal Warming, Aesthetics, No Reduction in Volume
Water Quality Inlets/Tanks	Limited Nutrient Removal, No Reduction in Volume

Conclusion

The common theme throughout the above is the lack of volume reduction. While this factor may not be of great concern if the wetland system is large enough in size, the desire to maximize on-site infiltration would not be addressed through these BMPs. Given the uncertainty surrounding natural infiltration techniques because of soil conditions, it was concluded that storage techniques would have to be coupled with infiltration techniques if they were to address the stipulated concerns.

3. Screen BMPs based on Site Conditions

a) Eliminate BMPs which Violate Physical Site Conditions

BMPs which rely upon natural infiltration for all or part of their function are of questionable use on this site because of the variable nature of the soils. Vegetative BMPs such as grassed swales, buffer strips and filter strips and landscaping techniques may be utilized, but should be treated as supplementary techniques only, in deciding upon the overall BMP plan. Structural infiltration devices are considered feasible.

b) Prioritize remaining BMPs based on land use constraints

The site plan essentially precludes the use of porous pavement since there are two levels of parking underneath the paved area of the site. The underground parking also limits the effectiveness of grassed swales and filter strips.

There is very little space available on-site to provide any type of surface storage retention/detention facility. The lack of space on-site requires either the use of the waterfront park for the location of any "on-site" stormwater quality controls or a reduction in the level of development. The use of the waterfront park for stormwater quality controls precludes the use of wetlands, an infiltration basin, a wet pond and an extended detention dry pond due to the incompatibility of these BMPs with the intended land use.

With respect to bacterial control the potential methods include detention for die-off, infiltration, and disinfection using either U-V light or ozone. Either of the first two are preferable to disinfection at the individual site level. Each type of disinfection requires continual operation and maintenance and therefore are more amenable to regional facilities operated by the municipality.

Based on the above potential, BMPs were divided into two groups:

<u>Priority 1 (Preferred BMPs based on development constraints)</u>

Water Quality Inlet/Storage Tank
Infiltration trench
Seepage Trench

<u>Priority 2 (Other physically feasible BMPs)</u>

Wet Pond
Extended Detention Pond
Infiltration Basin
Porous Pavement
U-V Disinfection
Ozonation

4. Assess Opportunities Presented by Different BMPs

The BMPs listed above may be eliminated from further consideration if the are redundant. In order to be classified as redundant, the following conditions must be met:

- elimination of the BMP cannot result in a use concern not being addressed
- the BMP does not offer opportunities which could not be pursued in conjunction with other BMPs

Based on the characteristics of the priority 1 BMPs, the infiltration trench can address all use concerns, while the water quality inlet/storage tank would require addition controls to address volume reduction and bacteria control.

The following are a listing of potential opportunities associated with the potential BMPs:

<u>Priority 1 BMPs</u>

Water Quality Inlet/Tank	no thermal impact, no concern for public safety, spills control
Infiltration Trench	volume reduction, no thermal impact, no concern for public safety, aesthetically acceptable
Seepage Trench	volume reduction, no thermal impact, no concern for public safety, aesthetically acceptable

<u>Priority 2 BMPs</u>

Wet Pond	**habitat (aquatic and wildlife), landscape amenity, recreational amenity, aesthetic enhancement**
Extended Detention Pond	**habitat (limited aquatic, wildlife), recreational amenity**
Infiltration Basin	volume reduction, no thermal impact, no concern for public safety, aesthetics only moderately acceptable
Porous Pavement	volume reduction, no thermal impact, no concern for public safety, aesthetically acceptable
U-V or Ozone Disinfection	no concern for public safety

NOTE: opportunities in bold print are those which offer significant potential improvements over the priority 1 BMPs.

Examining the opportunities provided by the priority 2 BMPs, the infiltration basin and the porous pavement options offer no opportunities over the infiltration trench and may be eliminated, contingent upon this option being pursued. The disinfection options similarly provide no significant opportunities and may be eliminated, so long as bacterial control is provided by the BMP plan. The pond opportunities associated with recreational or landscape amenities were deemed to be inappropriate given the overall plan

for the (lakefront location, park/boardwalk setting). The habitat opportunities were similarly deemed to be insignificant because of the small site size, the current and surrounding land uses, and the proposal to create a larger wetland area as part of the overall development plan.

On the basis of the above, it was decided to formulate a BMP scenario using the priority 1 options only.

5. Select BMPs

a) Identify BMPs or groups of BMPs for pre-design calculations

The following table was formulated to assist in scenario development and to ensure that all use concerns were addressed by the selected combination of BMPs.

Table 6.13 BMP Selection Chart (Example)

Type of BMP	Volume Reduction	Recreation	Fisheries Reduction	Aesthetics	Sum
Storage Tank			X	X	2
Infiltration Trench	X	X	X	X	4
Seepage Trench	X	X	X	X	4

Table 6.13 indicates that either an infiltration trench or seepage trench could provide the level of water quality protection expected at the on-site level. The seepage trench would essentially be the same as the infiltration trench except that it would only accept runoff from the rooftop and not the entire site. This would require a dual minor system since the trench would be located in the waterfront park. Because of concerns regarding runoff from the remainder of the site a water quality inlet, probably with disinfection, would be required in addition to the seepage trench. As such, an infiltration trench would be a more efficient means of addressing the same concerns as the seepage trench.

It is concluded therefore, that an infiltration trench is the preferred BMP solution for this particular site. In order to extend the life of the trench (prevention of sedimentation clogging the trench), and accommodate spills, the trench will be designed with a pre-treatment BMP (water quality inlet).

b) Identify Capital and O & M costs for selected BMP solutions

In order to cost the BMPs they must be sized. An analysis of the Black Creek watershed with the Bloor St. precipitation gauge produced the following target runoff volumes for the 0.916 ha area :

Summer runoff -	67 m^3	(72 hour detention with 4 overflows/season) (20 mm per impervious hectare)

The costing was calculated as a present value for 100 years of operation and maintenance with an average interest rate of 8 %. The present value cost includes the estimated cost of replacement, and thus, BMP service life.

Infiltration Trench

Exfiltration

The summer runoff volume can be down-sized based on some of the influent stormwater infiltrating during the storm itself. The percolation rate of the soil was assumed to be that of a loam :

Percolation rate = 10 min/cm

The amount of percolation was based on an exfiltration area of 400 m^2, a porosity of 0.15 for the soil/filter bed, and a storm duration of 4 hours (4 hour Chicago). The exfiltration over 4 hours was calculated to be approximately 14 m^3. Therefore, the infiltration trench was sized to provide a storage volume of 53 m^3 (approximate depth of 0.4 m).

Pre-Treatment

Pre-treatment of runoff was costed based on 28 m^3 of wet storage per impervious hectare (Schueler, 1987).

Land Costs

In this particular scenario land costs were not relevant since the infiltration trench was compatible with the intended parkland use. Because of the subsurface nature of the BMP, recreational use could be made of the area. There was no anticipated reduction in the value of recreation compared to the original parkland design. This will not be the case in most development plans, and as such, land costs would have to be calculated.

Water Quality Inlet

Specifications :

Length	8 m
Height	2.5 m
Width	1.5 m

Table 6.14 Water Quality Inlet Capital Costs			
Material	**Amount**	**Unit Cost**	**Cost**
Concrete	16 m^3 *	\$ 600/m^3	\$ 9,600
Inverted Elbow	1 m	\$ 300/m	\$ 300
Trash Rack	1.5 m^2	\$ 100/m^2	\$ 150
Excavation	30 m^3	\$ 10/m^3	\$ 300
Outlet Pipes	5 m (x 4)	\$ 200/m	\$ 4,000
Seed and Topsoil	12 m^2	\$2.50/m^2	\$ 30
Total Capital Cost			\$ 14,380

* Inlet Dimensions (Outer 8 m (L) x 2.5 m (H) x 1.5 m (W)) (walls are 200 mm thick)

Table 6.15 Water Quality Inlet Maintenance			
Maintenance	**Interval**	**Unit Cost**	**Total Cost**
Cleanout	3 x per year	\$ 1,900	\$ 5,700 per year
Replacement	30 years	\$ 14,380	\$ 14,380 / 30 years

The approximate total cost of the water quality inlet based on a 100 year present value would be \$ 87,200

Infiltration Trench

Specifications :

Area	400 m^2
Pipe Cover	1.2 m
Gravel Depth	0.4 m at n=0.4
Sand Filter Depth	0.2 m at n=0.15

Table 6.16 Infiltration Trench Capital Costs

Material	Amount	Unit Cost	Cost
Filter Cloth	400 m^2	\$ 10/m^2	\$ 4,000
Pervious Pipes	16 pipes 20 m long	\$ 15/m	\$ 4,800
Sand Filter	80 m^3	\$ 40/m^3	\$ 3,200
Gravel Storage	160 m^3	\$ 40/m^3 *	\$ 6,400
Excavation	720 m^3	\$ 10/m^3	\$ 7,200
Overflow Pipe	20 m	\$ 200/m	\$ 4,000
Seed and Topsoil	400 m^2	\$ 2.50/m^2	\$ 1,000
Observation wells	2 m	\$ 150/m	\$ 300
Total Capital Cost			\$ 30,900

* typical diameter = 25 mm

Table 6.17 Infiltration Trench Maintenance

Maintenance	Interval	Unit Cost	Total Cost
Grass Cutting	12 x per year	\$ .025/m^2	\$ 120 per year
Replacement	15 years	\$ 30,900	\$ 30,900 / 15 years

The approximate total cost of the infiltration trench based on a 100 year present value would be <u>\$ 46,600</u>

Therefore, the 100 year cost for the BMP solution for this site (water quality inlet and infiltration trench) would be <u>\$133,800</u>.

c) **Select BMP solution based on a comparison of BMP costs, level of protection provided by the BMP solution, and opportunities provided by the solution.**

There is no need to compare alternatives since only one solution was identified as being feasible for the water quality goals and site conditions.

d) **Identify any problems which must be addressed outside of the BMP design**

The BMP design will address all of the downstream water quality concerns identified, reducing the volume of water transmitted to the regional wetland facility, ensuring a reduction of bacteria loading from the site, and reducing solids and contaminant loadings from the site. In addition the solution does not have any negative aesthetic impacts.

The requirement for pre-treatment to extend the service life of the facility, will have ancillary benefits in terms of spill control. The majority of recorded spills in urban settings are small volume gasoline spills as a result of traffic accidents.

6.2.3 Summary of Integrated Design Examples

The preceding two examples show the steps involved in the selection of a BMP solution for a particular development scenario. The process is not intended to converge on one BMP or one combination of BMPs. Rather, it is intended to provide a selection of feasible BMPs based on identified concerns in the watershed.

The examples were kempt simple due to the illustrative nature of this section. As such, they were presented qualitatively. For example, although thermal impacts were identified as a concern, the optimum receiving water temperature was not identified. In some instances a wet pond could be designed with dimensions and shading which would satisfy these thermal impact concerns. Hence, the sensitivity of each water quality concern in a watershed context must be reviewed when selecting BMPs. In the first example, it was assumed that there was a sensitive cold water fishery in the receiving waters (18°C) and that a wet pond could not be designed to maintain this diverse fishery.

The reviewing agencies usually have a general idea of whether a wet pond would satisfy downstream temperature concerns based on their personal knowledge of the sensitivity of the receiving waters. It is not expected that a temperature modelling exercise will be required during the design of a BMP. However, it is up to the BMP designer to satisfy the reviewing agencies that a wet pond and any additional design features can control the temperature to the level desired. Reviewing agencies must be open to analyses or supporting literature which provide information to the expanded utility of different BMPs and specific design features which expand the utility of a BMP. Reviewing agencies should not rely solely on agency "policy/criteria" and their own personal BMP experience when judging the acceptability of a BMP.

This type of selection process ensures that watershed, tributary, and site specific water quality concerns are addressed while allowing the BMP designer the flexibility to produce innovative designs.

It is recognized that a flexible BMP selection process could be problematic for designers unfamiliar with BMP technology. As such, the process has been designed to screen out BMPs which are incompatible with watershed goals. Further, the process tends to inherently over-design BMP solutions because it does not consider spring and summer operation BMPs to be working in series. This will provide a safeguard for designers unfamiliar with the positive and negative aspects of BMPs.

Once a BMP solution has been selected, experienced BMP designers can make another iteration to optimize the sizing of BMP components (if the BMP solution comprises more than one type of BMP).

7.0 BMP CAPITAL COSTS

There is a lack of data for BMP capital costs in Ontario. Data was available from the Washington area concerning different BMP costs (Wiegand et al., 1986, Schueler, 1987), but these costs were not directly applicable due to different labour and material costs in Canada compared to the United States.

7.1 Ontario Based Capital Costs

Representative costing for Ontario BMPs was extrapolated from individual labour and material costs. Contingency costs, which include planning, design, and overseeing construction, were not included. It would be expected that the contingency fees for stormwater quality facilities will be somewhat higher than for stormwater quantity facilities due to the multi-disciplinary aspect of BMP design (involves hydrogeologists, landscape architects, engineers, fishery biologists, etc.). After the introduction of BMP technology, contingency fees can be expected to decrease, however, since standardization of design features and construction practices will occur.

The following tables provide an estimate of capital costs for the different BMPs.

Table 7.1 Extended Detention Dry Ponds

Type of Construction	Unit	Price
Excavation (must be transported off the site) Earthworks (cut and fill on-site)	m^3 m^3	\$ 10 \$ 3
Low flow channel	m	\$ 50
Rip Rap (Low flow, Outlet, Spillway)	m^2 *	\$ 50
Riser with hood (CMP or Concrete)	-	\$ 1500 - \$ 6000
Extended Detention Orifice (300 mm) with cap	m	\$ 400
Outlet Pipe - concrete (450 mm) with collar	m	\$ 200
Vegetation (Upland area)	m^2	\$ 1

* nominal depth = 450 mm

Table 7.2 Wet (Retention) Ponds		
Type of Construction	**Unit**	**Price**
Excavation (off-site disposal) Earthworks (on-site cut and fill)	m^3 m^3	$ 10 $ 3
Rip Rap (Inlet, Outlet, Spillway)	m^2 *	$ 50
Riser (CMP or Concrete)	-	$ 1500 - $ 6000
Outlet Pipe - concrete (450 mm) with collar	m	$ 200
Vegetation (Aquatic area)	m^2	$ 0.50
Vegetation (Upland area)	m^2	$ 1

* nominal depth = 450 mm

Table 7.3 Storage Tanks/Water Quality Inlets		
Type of Construction	**Unit**	**Price**
Excavation (off-site disposal) Earthworks (on-site cut and fill)	m^3 m^3	$ 10 $ 3
Access Manhole (1200 mm)	m	$ 800
Cast in Place Chamber (re-enforced concrete)	m^3	$ 600
Inverted Elbow (oil chamber)	m	$ 300
Trash Rack (grit/sediment chamber)	m^2	$ 95
Seed and Topsoil	m^2	$ 2.50

Table 7.4 Infiltration Basins		
Type of Construction	**Unit**	**Price**
Excavation Earthworks (cut and fill on-site)	m^3 m^3	$ 10 $ 3
Rip Rap (Inlet and Spillway)	m^2 *	$ 50
Perforated Pipe (100 mm)	m	$ 15
Seed and Topsoil	m^2	$ 2.50

* nominal depth = 450 mm

Table 7.5 Infiltration Trenches		
Type of Construction	**Unit**	**Price**
Excavation	m^3	$ 10
Clean Stone (Gravel)	m^3 *	$ 40
Filter Cloth	m^2	$ 10
Filter Material (Sand)	m^3	$ 40
Observation Well (100 mm PVC)	m	$ 150
Overflow Pipe (450 mm) concrete	m	$ 200
Perforated Pipe (100 mm)	m	$ 15
Seed and Topsoil	m^2	$ 2.50

* typical diameter = 25 mm

Table 7.6 Porous Pavement		
Type of Construction	**Unit**	**Price**
Excavation	m^3	\$ 10
Clean Stone (Gravel)	m^3 *	\$ 40
Porous Pavement (Pavement minus fines)	m^2	\$ 15
Filter Material (Sand)	m^3	\$ 40
Observation Well (100 mm PVC)	m	\$ 150
Overflow Pipe (450 mm) concrete	m	\$ 200
Perforated Pipe (100 mm)	m	\$ 15
Signs	each	\$ 200

* typical diameter = 25 mm

Table 7.7 Filter Strips		
Type of Construction	**Unit**	**Price**
A) Turf Filter Strips		
Topsoil, grading, sodding and spreader construction	m^2	\$ 4.50
Hydroseeding, grading, mulch and spreader construction	m^2	\$ 2.50
B) Wooded Filter Strips		
Grading, tree and shrub planting, and spreader	m^2	\$ 15
C) Retrofit Filter Strips (Wooded or Turf)		
Local grading	m^2	\$ 0.70
Spreader construction	m^2	\$ 0.55

Table 7.8 Grassed Swales		
Type of Construction	**Unit**	**Price**
Sodded swale	m	$ 30

Vegetation and conservation in conjunction with other types of BMPs is often ignored due to the myriad of combinations of vegetation, conservation, and BMP facilities. Both conservation and use of vegetation with structural BMPs are discussed in the following sections.

7.2 Vegetation Use with Structural BMPs

In this section structural BMPs refer to BMP facilities such as wet ponds, dry extended detention ponds, infiltration trenches, tanks, infiltration basins, and water quality inlets. These structural BMPs can be further classified in terms of environmental zones to determine the applicability of different types of vegetation in each zone.

These environmental zones are described as:

i) **Aquatic Zone** - permanent pool - water depth .3-2m. This zone exists in wet ponds BMPs.

ii) **Aquatic Fringe Zone** - Permanent pool - water depth 150 mm to 300 mm. This zone exists in wet ponds and shallow marshes.

iii) **Wetland Fringe Zone** - Regular inundation during all storm events. This zone exists in wet ponds, and shallow marshes.

iv) **Floodplain Zone** - Periodic inundation during storm events (< 5 year storm). This zone exists in wet ponds, extended detention ponds, infiltration basins, and dry ponds.

v) **Lowland Zone** - Periodic inundation during large storm events (> 5 year storm). This zone exists in all basin BMPs.

vi) **Upland Zone** - Inundated only in severe storm events. This zone exists on the upper slopes of all basin BMPs.

Table 7.9 Vegetation Capital Costs			
Environmental Zone	Vegetative Practices	Unit	Price
Aquatic	Aquatic plant material (limited availability)*	m^2	\$.35-\$1.0
Aquatic Fringe	Plants by seed, bare root, rhizomes, or pot	m^2	\$.35-\$1.0
Wetland Fringe	Planting Riverstone - 150 mm depth Boulders	m^2 m^2 each	\$.35-\$1.2 \$ 25 \$100-\$200
Floodplain	Hydroseeding Sodding Plants, deciduous & coniferous trees, shrubs **	ha ha ha	\$ 7500 \$ 32500 \$3500-\$20000
Lowland	Hydroseeding Sodding Plants, deciduous & coniferous trees, shrubs **	ha ha ha	\$ 7500 \$ 3250 \$3500-\$20000
Upland	Hydroseeding Sodding Plants, deciduous & coniferous trees, shrubs **	ha ha ha	\$ 7500 \$ 32500 \$3500-\$20000

* Planting of aquatic zone is optional (Aquatic Fringe should grow into Aquatic Zone once it becomes sustained (several years))

** Trees are based on seedling prices and specific spacing (deciduous - 8m on centre, coniferous - 3m on centre)

7.3 Capital Cost of Conservation as a BMP

The preservation of existing vegetation within a proposed development site is a practical and economical method of reducing the amount of runoff from a site through interception. Costs related to conservation of existing blocks of vegetation vary greatly depending on the following factors:

- Property value
- Proposed use and density
- Type and condition of vegetation
- Level of maintenance
- Size of area to be preserved
- Supplementary grading and planting required to mitigate the impact of development

A detailed assessment of existing site vegetation should be undertaken to determine the feasibility for preservation within the context of the development plan.

7.4 BMP Land Use Requirements and Approximate Costs

The area of land required by a BMP depends on the type of BMP, water quality concern, and performance criteria. Table 7.10 provides a rough estimation of the land requirements of different BMPs based on an average storage depth of 2 metres. It should be stressed that Table 7.10 is presented for comparison purposes only. It illustrates the range of BMP land requirements and the inapplicability of certain BMPs to accommodate various pollutant concerns without the inclusion of other BMP types.

Table 7.10 Approximate BMP Land Requirements (m^2/ha)

BMP Type	Spring Concern (24 h)	Cost for 1 Imperv. ha	Summer Concern (72 h)	Cost for 1 Imperv. ha	Summer Concern (Baseflow)	Cost for 1 Imperv. ha
Wet Pond	1250	$ 22,500	500	$ 13,000	250	$ 9,700
Extended Detention Dry Pond	250	$ 20,000	100	$ 13,500	50	$ 9,600
Infiltration Basin	250	$ 11,800	100	$ 4,700	50	$ 2,400
Infiltration Trench	625	$ 93,900	250	$ 39,700	125	$ 20,300
Porous Pavement	625	$ 94,600	250	$ 40,300	125	$ 20,800
Storage Tank	250	$ 58,000	100	$ 29,600	50	$ 19,200
Filter Strips	5000	$ 75,000	2000	$ 30,000	1000	$ 15,000
Grassed Swales	2500	$ 25,000	1000	$ 10,000	500	$ 5,000

Assumptions:
- storage depth of 2 metres
- average depth over filter strip of 100 mm
- average depth in swale of 200 mm
- width of swale = 3 m
- gravel porosity of 0.4
- permanent pool volume = storage volume (storage volume at a 7:1 slope)
- pre-treatment extra

The costs in Table 7.10 can not be extrapolated since they include costs which are not directly related to the area served by a BMP such as the outlet structure. These costs are approximate and should not be used for estimating actual design costs. Individual calculations should be made to determine the capital costs on a site specific basis.

Table 7.10 demonstrates that wet ponds require a much greater area than dry ponds, and that vegetative BMPs require the greatest amount of land area when used as the only BMP to control the stormwater volume. Table 7.10 also indicates that surface storage techniques are the most economical for large volumes of stormwater, and that subsurface infiltration techniques are expensive compared to other BMP techniques. Subsurface infiltration BMPs are expensive due to the high cost of gravel, and the inefficiency of using pore space for storage volume .

8.0 OPERATION AND MAINTENANCE OF BMPS

8.1 Guidelines for BMP Maintenance Responsibility

Developer

It is recommended that the developer be responsible for the operation and maintenance of local BMPs for a minimum period of two years from the completion of the development. The developer would be responsible for ensuring that the necessary monitoring is performed, and that any required maintenance is carried out during this time. Additional requirements e.g. monitoring may be placed on the developer if there are insufficient results or the facility violates the compliance limits.

If the monitoring indicates that the BMP fails to meet the non-compliance pollutant removal targets, the developer would be responsible for rectifying the BMP design/construction such that non-compliance targets are equalled or exceeded.

This initial probationary period reflects the "polluter pays" concept. The development industry is like any other business, it needs to be regulated to ensure that the environment is not degraded as a result of "manufacturing processes". Responsible developers understand this, and are willing to implement water quality controls. In the same way that stormwater should be viewed as a resource instead of a waste, developers should be recognized as an integral part of the water quality solution instead of a source of water quality problems.

Developers would also be expected to pay fees based on contributing developed area for the construction, operation, and maintenance of regional BMP facilities implemented by the local municipality for the same duration of 2 years after BMP construction. If the regional facility is constructed before development occurs, the municipality must expect to pay for the BMP and collect the fees as the land becomes developed. This recommendation also reflects the concept of "polluter pays".

The development industry should recognize that the emphasis on watershed planning as it relates to water quality and quantity will result in more cost-effective stormwater management facilities. In addition, compulsory new development monitoring will result in more cost effective BMP designs for the future.

Municipality

The municipality will be responsible for all operational and maintenance functions after the minimum 2 year probationary period. The municipality will be responsible for compiling the monitored data provided by the developer so that it can be incorporated into a province wide BMP database.

The monitoring program can be relaxed after the 2 year probationary period but cannot be discarded. The BMP facility must be checked at least once every 3 years to ensure that it is operating efficiently.

The municipality could set up a monitoring program which would rotate samplers from BMP to BMP in the municipality. If the monitoring indicates that the BMP is not operating up to non-compliance standards remedial action must be taken to correct the problem. This may involve additional monitoring to confirm a problem, maintenance, or actual reconstruction of the facility.

8.2 BMP Maintenance Functions and Cost

Annual and periodic maintenance is required for BMPs to function as designed. The effectiveness of a BMP over time is directly linked to the amount of maintenance which is performed.

The costs associated with BMP maintenance vary with BMP type and size. It should be recognized, however, that there is a significant cost associated with environmental maintenance using BMPs, since there will be a requirement to provide numerous local facilities, all of which will require maintenance.

Maintenance functions and costs for each BMP are provided in the following tables.

Table 8.1 Wet (Retention) Pond Maintenance Costs			
Type of Maintenance	**Interval**	**Unit**	**Price**
Aquatic zone litter removal	Annual	m^2	$ .20
Grass Cutting	12 x /yr	m^2	$ .025
Weed Control (Upland zone)	Annual	m^2	$ .10
Vegetation planting (Upland zone)	5 years	m^2	$ .10
Silt removal (Upland zone)	5 years	m^2	$ .40
Sediment removal (Aquatic zone) Dredging	15 years		
> 100 m^3 removal disposal (sanitary landfill)		 m^3 m^3	 $10-15 $ 50
< 100 m^3 removal labour (minimum of 4 hours) mobilization cost (cost of moving equipment) disposal (sanitary landfill)		 h - m^3	 $ 100 $ 4000 $ 50
Sediment removal (Aquatic zone) Non-Dredging	15 years		
removal labour (minimum of 4 hours) disposal (sanitary landfill)		h m^3	$ 100 $ 50

Table 8.2 Dry Extended Detention Pond Maintenance Costs			
Type of Maintenance	**Interval**	**Unit**	**Price**
Grass Cutting	12 x /yr	m^2	$ .025
Weed Control (Upland zone)	Annual	m^2	$ .10
Vegetation planting (Upland zone)	5 years	m^2	$ .10
Silt removal (Upland zone)	5 years	m^2	$ .40
Sediment removal (Wetland Fringe zone)	5 years		
removal labour (minimum of 4 hours) disposal (sanitary landfill)		h m^3	$ 100 $ 50

Table 8.3 Storage Tank/Water Quality Inlet Maintenance Costs			
Type of Maintenance	**Interval**	**Unit**	**Price**
Sediment/Oil removal (Vacuum) - Water Quality Inlet	2 x /yr		
cleaning		-	\$ 500
testing		-	\$ 100
disposal (sanitary sewer)		-	\$ 1300
Sediment removal (Manual) - Storage Tank	15 years		
removal labour (minimum of 4 hours)		h	\$ 100
disposal (sanitary landfill)		m^3	\$ 50

Table 8.4 Infiltration Trench Maintenance Costs			
Type of Maintenance	**Interval**	**Unit**	**Price**
Grass Cutting	12 x /yr	m^2	\$ .025
Sediment/Oil removal (Vacuum) - Water Quality Inlet	2 x /yr		
cleaning		-	\$ 500
testing		-	\$ 100
disposal		-	\$ 1300

Table 8.5 Infiltration Basin Maintenance Costs			
Type of Maintenance	**Interval**	**Unit**	**Price**
Grass Cutting	12 x /yr	m^2	$ .025
Litter Removal	Annual	m^2	$ .20
Tilling (Discing of basin floor to improve infiltration)	Annual	h	$ 100
Re-establish vegetation on basin floor	Annual	m^2	$ .20
Sediment removal (Wetland Fringe zone)	5 years		
removal labour (minimum of 4 hours)		h	$ 100
disposal (sanitary landfill)		m^3	$ 50

Table 8.6 Porous Pavement Maintenance Costs			
Type of Maintenance	**Interval**	**Unit**	**Price**
Pavement Sweeping/Vacuuming	4 x /yr		
labour		h	$ 100
sediment removal		m^3	$ 45
Jet Washing	4 x /yr	m^2	$ 100 *
De-icing chemicals (additional cost compared to salt)	Annual		
Urea		kg	$ .30
Dynomelt		kg	$ .50

* Not currently available in Ontario - price is estimated

Table 8.7 Filter Strip Maintenance Costs (Turf)			
Type of Maintenance	Interval	Unit	Price
Grass cutting	12 x /yr	m^2	\$ .025
Weed control	2 x /yr	m^2	\$ .05
Local grading to maintain flow	Annual	m^2	\$ .10
Fertilization	3 x /yr	m^2	\$ .035
Spreader maintenance	Annual	m^2	\$ .05
Spreader reconstruction	5 years	m^2	\$ .40
Grading and Seeding	5 years	m^2	\$ .85

Table 8.8 Filter Strip Maintenance Costs (Wooded)			
Type of Maintenance	Interval	Unit	Price
Local grading to maintain flow	Annual	m^2	\$ .10
Supplementary planting	Annual	m^2	\$ .15
Spreader maintenance	Annual	m^2	\$ .05
Spreader reconstruction	5 years	m^2	\$ .40
Grading	5 years	m^2	\$ .65

Table 8.9 Grassed Swale Maintenance Costs			
Type of Maintenance	Interval	Unit	Price
Grass cutting, litter removal, weeding	Annual	m	\$13.50
Grading, Overseeding	5 years	m	\$ 8

Table 8.10 Vegetation Maintenance Costs				
Environmental Zone	**Vegetative Practices**	**Interval**	**Unit**	**Price**
Aquatic Aquatic Fringe Wetland Fringe	Litter and debris removal Sediment removal, deplanting, grading	Annual 5 Years	m^2 m^2	$ .20 $.35-1.0
Floodplain Lowland Upland	Grass cutting Weed control	12 x /yr Annual	m^2 m^2	$ 0.025 $ 0.10

8.3 Sediment Disposal Costs

The cost to dispose of sediment will vary depending on the quality of the sediments. The sediment must be tested to determine the level of contamination, and hence, disposal options.

The costs which were provided in Section 8.1 provide for the disposal of the sediments in a sanitary landfill site. If the sediment can be classified as clean fill, and can be disposed of on-site, the disposal cost would be negligible. Conversely, if the soil is so contaminated that it must be classified as a registerable waste, the cost will be significantly higher ($150/hr (min. of 4 hours) hauling cost and $50/$m^3$ disposal costs).

The disposal of sediment on-site would constitute the most economical method of sediment removal. The feasibility of this option will be determined by the analysis of the sediment. Since there have not been many analyses performed on BMP sediment, it is not possible to predict the disposal options for the sediment. Therefore, it is recommended that the site plan should accommodate on-site disposal of sediment, so that the least cost option of disposal can be utilized if allowable.

Another option for reduced maintenance costs would be to oversize surface storage BMPs to reduce the required frequency for maintenance. This may have implications on bioaccumulation of contaminants in benthic organisms in the pond, and requires further research.

8.4 Replacement Costs

There are replacement costs which should be considered when attempting to estimate the cost of BMPs over a protracted length of time. These costs relate to the replacement of items such as risers due to the service life of concrete or corrugated metal piping, and infiltration filter beds due to the inevitability of clogging in infiltration devices due to sediment loading.

The estimation of service life for BMPs such as infiltration trenches, infiltration basins, and porous pavement is unknown, since systems designed for stormwater quality have only been in place for 5-7 years. The high failure rate of infiltration BMPs in the United States can be partially attributable to contractor unfamiliarity with design practices for these facilities. Over-compaction, or poor sediment control during construction, will render an infiltration device ineffective no matter how well it was designed.

Estimation of service life for various components of BMPs are provided in Table 8.11.

Table 8.11 Estimated Service Life of BMP Components

Material	BMP Component	Estimated Service Life
Corrugated Metal Pipe	Risers (wet & dry ponds)	15 years
Concrete Pipe	Inlet/Outlet pipes, Risers	30 years
Filter beds	Infiltration Trenches Porous Pavement	15 years

Replacement costs for BMPs can be minimized by design. For instance, filter cloth could be placed on top of both the gravel layer and the sand layer in infiltration trenches to trap sediment. This would confine the replacement of the trench to the gravel layer (ie. the entire trench would not have to be replaced). Likewise, concrete outlet structures could be used instead of corrugated metal pipe to prolong the service life of a facility.

9.0 PROPOSED WORK PROGRAM

9.1 BMP Research

Several areas of research were identified in Section 2 as being required to enhance the current knowledge of BMP operation and effectiveness for Ontario conditions. These areas of research included :

- BMP operation under winter/snowmelt conditions
- Impact of dissolved versus suspended solids on water quality
- Effects of re-suspension of settled solids
- Receiving water improvements from the implementation of BMPs
- Standard monitoring methods for BMPs
- Bio-accumulation of stormwater pollutants
- Standards for Ontario BMP design
- First flush of pollutants on a watershed basis

The funds for BMP research must be provided by the provincial government, namely the Ministry of Environment (MOE) and the Ministry of Natural Resources (MNR) since local municipalities and conservation authorities do not have the budget to undertake purely research oriented projects.

The research can be implemented by a joint venture between the local municipality and the conservation authority. Monitoring of the BMPs could be performed by the conservation authority while operational and maintenance tasks would be performed by the municipality. The implementation of the projects should be supervised by the provincial government to ensure that consistent standards are utilized across the province.

9.2 BMP Research Monitoring

Section 2 indicated that research monitoring should be conducted on BMPs under winter/snowmelt conditions. It was noted that this research should focus on the effects of ice cover on wet ponds and the effectiveness of infiltration techniques under frozen/saturated soil conditions.

Year round monitoring of the hydraulic properties of infiltration BMPs will provide an opportunity to monitor the quality of exfiltrated water, and hence, the potential for groundwater contamination. The effect of infiltration BMPs on groundwater contamination was another area identified in Section 2 requiring further research.

9.2.1 Infiltration BMP Monitoring

Groundwater Quality

The required frequency of groundwater quality monitoring is less stringent than surface water quality monitoring since groundwater has a much longer residence time than surface water. Monthly measurements of groundwater quality are recommended to provide sufficient detail on the effect of infiltration BMPs on groundwater quality.

Table 9.1 outlines the installation costs for an infiltration BMP with 4 sampling locations.

Table 9.1 Groundwater Quality Monitoring Installation Costs (4 Piezometers)			
Item	Unit Cost	Quantity (4 Piezometers)	Total
Drilling	$ 110 /hr	15 hours	$ 1,650
Equipment Mobilization	$ 2 /km	300 km	$ 600
Pipe (3.4 m lengths)	$ 31	8 lengths	$ 248
Screen (3.4 m lengths)	$ 54	4 lengths	$ 216
Bentonite (Volplug #50)	$ 16 /bag	4 bags	$ 64
Sand (45 kg silica)	$ 18 /bag	4 bags	$ 72
Protector	$ 95	4	$ 380
Caps	$ 2	4	$ 8
Cement	$ 15 /bag	4	$ 60
Locks	$ 10 /lock	4	$ 40
Waterra Tubing	$ 1 /m	48 m	$ 48
Waterra Foot Valves	$ 19 /valve	4 valves	$ 76
Shipping	$ 10	1	$ 10
In-line Filters	$ 27	4	$ 108
Groundwater Analysis	$ 435 *	4 samples	$ 1,740
Sieve/Hydrometer Analysis	$ 65	8 samples	$ 520
Manpower	$ 55 /hour	40 hours	$ 2,200
Disbursements (Travel, Meals, Clerical)	$ 266	1	$ 266
Total Installation Costs			$ 8,307

Table 9.2 provides an estimate of the annual monitoring costs for an infiltration BMP with 4 sampling locations.

Table 9.2 Annual Groundwater Quality Monitoring Costs			
Item	Unit Cost	Quantity (4 Piezometers)	Total
Manpower (Sampling)	\$ 54 / hour	48 hours	\$ 2,592
Manpower (Report Writing)	\$ 75 /hour	24 hours	\$ 1,800
Manpower (Drafting)	\$ 44 /hour	8 hours	\$ 352
Disbursements (Travel, Meals, Clerical)	\$ 190	12 times / year	\$ 2,280
Groundwater Analysis *	\$ 435 /sample *	58 samples	\$ 25,230
Annual Monitoring Costs			\$ 32,263

* analyses include 26 metals, 7 anions, pH, alkalinity, ammonia nitrogen, ortho-phosphorous, dissolved organic carbon, NO_2-N, total dissolved solids, hardness, conductivity, chlorides, phenols, oil and grease, BOD, total Kjeldahl N, nitrate nitrogen, total suspended solids, and total phosphorous (annual monitoring includes extra samples for duplicates)

Table 9.2 indicates that the cost of monitoring is driven by the number of samples which are analysed. The present value of a 5 year monitoring program of groundwater quality would cost $137,125 based on Tables 9.1 and 9.2.

Percolation Monitoring

Percolation monitoring is required to determine the effectiveness of infiltration BMPs under freeze/thaw conditions in the soil. Continuous monitoring is necessary, since the BMP effectiveness during the entire spring freshet, and the variation in effectiveness with season, must be determined.

Although it has been suggested that infiltration techniques are probably not suitable for spring quality control due to the high suspended solids loading (regardless of freeze/thaw effects) this research is required to determine the hydraulic operation of infiltration techniques during the spring. Water table monitoring will also lead to the refinement of infiltration BMP design criteria for spring and summer conditions in Ontario, and is efficiently incorporated with the groundwater quality monitoring study.

Table 9.3 Infiltration Techniques Percolation Installation Costs

Item	Unit Cost	Quantity (4 Transducers)	Total
Vibrating Wire (18 mm) *	$ 725	4	$ 2,900
Readout Box	$ 3,400	1	$ 3,400
Tipping Bucket Rain Gauge	$ 850	1	$ 850
32 Channel Datalogger (12 transducers)	$ 9,400	1	$ 9,400
Software	$ 400	1	$ 400
Electric Cable	$ 3 /m	600 m	$ 1,800
Manpower	$ 54 /hour	15 hours	$ 810
Disbursements (Travel, Meals, Clerical)	$ 266	1	$ 266
Total Installation Costs			$ 19,835

* does not include cost of piezometer since it is included in Table 9.1 (approximately $ 2,100 each)

Table 9.4 Infiltration Techniques Percolation Monitoring Costs

Item	Unit Cost	Quantity (4 Transducers)	Total
Manpower (Data Retrieval)	$ 54 /hour	200 hours	$ 10,800
Manpower (Data Analysis)	$ 68 /hour	200 hours	$ 13,600
Manpower (Report Writing)	$ 75 /hour	40 hours	$ 3,000
Manpower (Drafting)	$ 44 /hour	16 hours	$ 704
Disbursements (Travel, Meals, Clerical)	$ 100 /trip	50 trips	$ 5,000
Annual Monitoring Costs			$ 33,107

It was anticipated that weekly trips to the research site would be required to download the data from the level recorder to a laptop computer. The recorders could be telemetered, but this would result in a significant increase in cost. Regular site visits are encouraged in any case since they allow the detection of operational or maintenance problems.

The cost of a 5 year monitoring program of water table depths based on Tables 9.3 and 9.4 would be $ 152,025. The total cost for a 5 year program monitoring both groundwater quality and water table depths would be approximately $ 290,250.

9.2.2 Pond Monitoring

It is recommended that continuous monitoring be implemented for surface storage BMPs. Monitoring locations should be provided at all inlets and outlets from the BMP facility. In most instances this should require only two monitoring locations.

The flow quantity recorder at each location would transmit signals to a water quality sampler at the same location to obtain flow proportional water quality samples. This would provide estimates of BMP efficiency based on mass loadings as opposed to pollutant concentrations.

An extra flow recorder would be required to monitor overflow volumes from the pond. The monitoring of overflows would assist in the determination of whether the pond sizing was commensurate with the desired level of water quality protection. An analysis of the overflows would provide recommendations for optimum pond sizing.

Table 9.5 Pond Monitoring Installation Costs			
Item	Unit Cost	Quantity	Total
Quality Sampler (flow proportional)	$ 6,200	2	$ 12,400
Flow Recorder	$ 5,300	3	$ 15,900
Tipping Bucket Rain Gauge	$ 850	1	$ 850
Equipment Housing	$ 1,000	2	$ 2,000
Manpower	$ 54 /hour	15 hours	$ 810
Disbursements (Travel, Meals, Clerical)	$ 266	1	$ 266
Total Installation Costs			$ 32,236

Table 9.5 presents the installation costs for a simple pond configuration (1 inlet and 1 outlet).

Table 9.6 Pond Monitoring Costs			
Item	Unit Cost	Quantity	Total
Manpower (Data Retrieval)	$ 54 /hour	200 hours	$ 10,800
Manpower (Data Analysis)	$ 68 /hour	200 hours	$ 13,600
Manpower (Report Writing)	$ 75 /hour	40 hours	$ 3,000
Manpower (Drafting)	$ 44 /hour	16 hours	$ 704
Disbursements (Travel, Meals, Clerical)	$ 100 /trip	100 trips	$ 10,000
Water Quality Analysis *	$ 435 /sample	120 samples	$ 52,200
Annual Monitoring Costs			$ 90,314

* analyses include 26 metals, 7 anions, pH, alkalinity, ammonia nitrogen, ortho-phosphorous, dissolved organic carbon, NO_2-N, total dissolved solids, hardness, conductivity, chlorides, phenols, oil and grease, BOD, total Kjeldahl N, nitrate nitrogen, total suspended solids, and total phosphorous (annual monitoring includes 20 % extra samples for duplicates)

Table 9.6 provides estimates on annual monitoring costs for a pond. The costs are based on bi-weekly trips to the site to download the flow data, and collect the water quality samples. It is recommended that the water quality samples be collected at least every 4 days to ensure accurate analyses.

The present value for a 5 year pond monitoring program based on Tables 9.5 and 9.6 would be $ 392,840.

9.3 Pilot Studies

Research monitoring will be carried out in the form of pilot studies. Ideally the pilot monitoring studies should not be based on existing BMPs since they were not chosen as a result of the selection process identified in Section 4. Likewise, the design storage volume for existing BMPs would probably be based on a design event and not the Ontario based hydrologic methodology proposed in Section 5. However, it is recognized that the delay imposed by the implementation of this process, and the approvals process for new water quality designs would slow the evolution of water quality designs. In addition, every effort should be made to compile Ontario-specific data to further BMP design improvements. Therefore, it is proposed that the pilot studies be segmented into two stages:

1. Demonstration studies : These monitoring projects would involve existing BMPs which may or may not have been designed specifically for water quality. This phase would also involve existing or proposed/approved BMPs which were not based on the selection/design process outlined in this study. These studies can be implemented immediately to provide some information concerning BMP operation and applicability.

2. Pilot Studies : These monitoring projects would involve BMPs selected using the process outlined in this study, and designed using continuous analysis. These studies will lag behind the demonstration studies due to the inherent delays in design, approvals, and construction of new BMP facilities.

9.3.1 Demonstration Studies

The demonstration studies are intended to provide basic information regarding the year-round operation of BMP techniques. As such, the monitoring will not be as extensive as a pilot study, nor will the monitoring timeframe be as long as a pilot study. A one to two year timeframe is recommended for demonstration studies. Monitoring may not necessarily be continuous throughout the year, but each site should be monitored for at least a three month period during the winter/spring period.

The implementation of demonstration studies can proceed immediately due to the nature and purpose of the studies. Several example sites are listed below which would be suitable for demonstration studies :

- Hanlon Creek infiltration/recharge ponds (Guelph)
- Toogood wet pond (Markham)
- Lake Wabukayne (ice effects) (Mississauga)
- Lake Aquitaine (ice effects) (Mississauga)
- Idlewood recharge pond (Waterloo)
- Pickering Plains infiltration basin (Ajax)
- Soper Creek Extended Detention Dry Pond (Oshawa)
- Cache Woods infiltration trench (Markham)
- Heritage Glen Extended Detention Wet Pond (Barrie)
- Brampton oil/grit separators (Brampton)
- Markville wet pond (Markham)
- Upper Middle Road wet pond (Burlington)
- Townsend wet pond (Nanticoke)
- Heart Lake Infiltration Pipe (Brampton)

The Rideau River BMPs have been specifically left out since there are current detailed efforts to manage water quality in the Rideau River watershed. Hence, any specification of demonstration studies in this area would be a duplication of effort.

It is again stressed that these monitoring exercises would not be exhaustive since most of these facilities were not designed with any specific criteria for water quality, nor were they designed based on continuous analysis.

9.3.2 Pilot Studies

The pilot studies will involve a more exhaustive assessment of BMP capabilities and design effectiveness. Therefore, it must be ensured that the BMP facilities which are monitored are selected based on the watershed concerns, and that they are designed based on Ontario climatic conditions. Only a few key sites should be comprehensively monitored since the level of monitoring would be cost-prohibitive on a large scale. In addition to providing information concerning the operation of BMPs in the Ontario climate, this type of monitoring should provide information on BMP monitoring itself, which could significantly reduce the needs and costs of new development and demonstration monitoring.

It is recommended that 6 infiltration BMPs and 3 wet pond BMPs be designed as pilot monitoring studies. Six infiltration BMPs are recommended due to the greater uncertainty of applicability during spring conditions, and the expanded range of infiltration techniques available (infiltration basins, infiltration trenches, and porous pavement).

These pilot studies should be initially funded for a period of 5 years. At the end of the five years the utility of extending the monitoring period should be reviewed. The decision to extend the monitoring period must be reviewed in the context of technological changes which have occurred in the treatment of stormwater quality, and the necessity of acquiring additional data to determine conclusions regarding BMP operation and effectiveness.

The requirements for implementation of stormwater BMPs in new developments is being adopted because of the recognized impacts of urban runoff on the environment. BMP designs must reflect actual site conditions and as such "off the shelf designs" will not be possible. Even with the guidance which will be provided by the design manual and expert system (to be developed in the next phase of this project) there will be a need for field verification of the operational effectiveness of each new BMP facility. It is recommended that the proponent be responsible for this compliance monitoring.

9.4 Biological Monitoring

9.4.1 Receiving Water Improvements from BMP Implementation

The most complex monitoring programs are those in which the improvements from the implementation of a BMP on the biotic community in the receiving body of water is to be assessed. In these cases, monitoring programs must not only monitor specified biota, but also hydrological and water quality changes associated with the BMP. Such changes can only be assessed if pre-operational baseline data are available and if control sites are available. Baseline data can only be collected prior to construction and operation of a BMP. Several years of baseline data are typically required, and as such, these programs may be prohibitively expensive, especially if the data derived is to be statistically conclusive. Given the probable costs of these programs, this type of monitoring would only be appropriate as part of pilot projects, research projects or very large-scale undertakings. It is recommended, however, that biological monitoring be undertaken in conjunction with selected pilot studies.

9.4.2 Biologically Useful Hydrological Monitoring

To be most useful, hydrological monitoring programs must consider several levels of resolution. At one extreme, they must detect and adequately describe changes in the runoff hydrograph. On the other hand, they should also enable description of hydrological changes in a manner which is meaningful in a biological context. This is particularly important if hydrological monitoring programs are to be linked to biological monitoring programs.

The starting point for the design of any biologically useful hydrological monitoring program is the identification of target indicator species (benthic invertebrates, aquatic plants or fish; and if fish, forage fish or sports fish).

Once the target species have been identified, then it is important to identify the hydrologic requirements of those species. This will enable hydrological sampling programs to be designed in such a manner that either relative or absolute changes in the habitat of those species, as defined in terms of hydrological requirements, can be described. For example, if it is known that a particular species requires pools of a particular size and depth, then changes in the availability of that habitat can easily be measured before and after implementation of a particular SWM BMP.

However, the design of a hydrological monitoring program relevant to the needs of a particular species must also consider the appropriate life stages. This decision must be based upon an understanding of the physical factors which limit the target species in that particular environment. As an example, it is possible that the hydrological changes resulting from implementation of a particular stormwater management plan could result in no changes to the juvenile rearing habitat for that species, while, at the same time, they could lead to the elimination of spawning habitat. Clearly, a monitoring programs which focused on juvenile rearing habitat would reach a different conclusion regarding the impacts (of a BMP) than a program which focused on spawning habitat.

9.4.3 Biological Effects Monitoring Programs

Careful design of sampling programs is essential if they are to be capable of detecting changes in biological communities attributable to implementation of stormwater management BMPs. Biotic communities, whether stable or unstable, are dynamic. In other words, they are constantly in a state of change, and monitoring programs must take this into consideration. A biotic community which is in dynamic equilibrium with its environment still exhibits changes, both spatially and temporally, however, these changes tend to follow predictable patterns and the magnitude of the changes tends to be limited within certain bounds.

Temporal changes in biological communities at particular locations can occur on a daily, seasonal or annual basis and monitoring programs must take these changes into consideration. Furthermore, the distribution and abundance of some species can also be markedly affected by periodic "events" such as storms and prolonged heat waves. Programs which fail to recognize the effects of these unique events will invariably reach inappropriate conclusions.

Spatial differences in the distribution and abundance of some species reflect differences in the suitability of different areas (habitats). While the physical characteristics of two sites may be identical, marked differences in the abundance of certain species may occur if there are other important (e.g. chemical) differences between sites.

Some species are better indicators of change (from a statistical perspective) than others in that their abundance and distribution are relatively unaffected by "normal" short-term changes in their physical and chemical environment. Obviously, the spill of a toxic contaminant is not a "normal" event and even species of the type described above will be affected. On the other hand, the distribution and abundance of other groups of species can be markedly affected by short-term changes in their physical and chemical environment. Benthic invertebrates, because of their relative lack of mobility,

tend to be good indicators of average conditions and, as such, are frequently used as indicators of pollution in aquatic ecosystems. However, benthic indicators are not considered "Valued Ecosystem Components" (VECs) (Holling, 1978). The most common VEC species are sports fish, waterfowl, other birds, etc.

The most significant challenge in designing a monitoring program is to design it in such a manner that changes attributable to the treatment (e.g., the new BMP) can be isolated from changes attributable to other factors unrelated to the treatment. To account for these natural variations, monitoring programs must include both "treatment" and "control" sites. They should also be conducted during both pre-treatment and operational years. Without pre-treatment sampling, there can be no true baseline data.

Biological effects monitoring programs can be designed to detect some or all of the following potential effects:

- changes in distribution and abundance of multi-species assemblages (i.e. community structure)
- changes in the distribution and abundance of single indicator species
- changes in biological attributes of particular species (growth rates, fecundity, incidence of tumours, etc.)
- bioaccumulation of contaminants

The program design will depend upon program objectives, as well as site specific details, and the kind of BMP system employed.

9.4.4 <u>Habitat Suitability Indices (HSI)</u>

Biological monitoring programs rarely focus exclusively on biological organisms. To do so would be to risk not identifying the linkages between cause (e.g., elevated nutrient levels) and effect (e.g., formation of algal mats over the stream bottom). Accordingly, in order to be most useful, biological sampling programs should be conducted in conjunction with water quality and quantity monitoring.

Conventional approaches to linking changes in physical and chemical variables to effects on biota are largely qualitative (e.g. the 50% increase in silt loading will have some negative impact on incubation success). However, in the last decade more quantitative approaches are available through the use of Habitat Suitability Indices (HSIs). HSIs have been developed for many aquatic fish species and a few benthic organisms, as well as for many waterfowl and wildlife species which associate with aquatic systems. The HSI approach provides a means of quantifying changes in the habitat of particular species, irrespective of the cause. Identification of changes in habitat availability is an important component of impact assessment.

HSIs are useful for quantifying changes in habitat availability but they do not account for changes in the abundance and distribution of particular species, or other biological attributes. These data can only be acquired through biological sampling programs.

9.5 New Development Monitoring

There will be a considerable expenditure of money with respect to water quality initiatives. In order to spend this money wisely, facilities which are constructed must be monitored to ensure that they are functioning according to their design specifications. This compliance monitoring is required to ensure that the downstream water quality objectives are met. It also has several ancillary benefits which justify the expenditure money for water quality improvement :

- it places responsibility of the design squarely with the design engineer who must ensure that his/her design meets compliance criteria
- it furthers our understanding of water quality improvements so that future designs can be fine-tuned with greater cost-savings

Compliance criteria must be less stringent than design criteria since there must be some provision for overflows during large runoff events during the brief monitoring period (ie. the design criteria were averages based over a long time period whereas the monitoring would be done over a relatively short time period).

The monitoring requirements for new development would consist of water quantity and quality monitoring for a minimum of two years. The following methodology provides an illustrative example of what could be required :

- Monitoring in the first year for a 4 month period between March and October
- Monitoring in the second year for a 2 month period between March and October
- Optional monitoring in the third year if there are insufficient results from first 2 years or first two years of monitoring show that the facility violates the compliance limits.

The compliance of a BMP must be based on a sufficient number of storms. Previous monitoring exercises emphasize the impact of operational difficulties on the collection of data. It must therefore be realized that the number of storms on which to base compliance must realistically be the minimum required to ensure statistical significance.

Compliance should be statistically calculated from the results of the monitoring based on the design criteria being within specified confidence limits of the monitored values. Since it is likely that the number of sample storms will be less than 30, the student t distribution should be used to calculate the confidence limits of the monitored data.

The enforcement of compliance would be the responsibility of the Ministry of the Environment. The cost and responsibility for the retrofit or re-design/re-construction of a facility would be borne by the developer. This would achieve several objectives :

- environmental quality would become a higher priority item in development planning
- consultants would have a greater responsibility for their work
- field supervision of construction activities would become more stringent to ensure that improper construction activities did not impair the operation of a BMP
- municipalities would not be left "holding the bag" for BMPs which required constant maintenance or had continual operational problems due to poor design and/or construction

If, after the 2 (or 3 if required) years of monitoring; the facility can be shown to achieve compliance, the ownership of the facility should be transferred to the local municipality. Hence, the local municipality would be responsible for the operation and maintenance of this facility once compliance had been demonstrated.

9.6 Ontario BMP Design Manual Work Program

9.6.1 Purpose of BMP Design Manual

Many consultants and regulatory personnel will be unfamiliar with stormwater quality control techniques. This lack of familiarization will impede BMP implementation and lengthen an already protracted approvals process. A design manual will provide the necessary background to familiarize consultants and regulatory agencies with the required decision tree process for mitigating stormwater quality impacts on receiving waters.

The BMP Design Manual serves several purposes :

- familiarizes and educates people with respect to BMPs
- demonstrates how watershed planning, and water quality goals are inextricably linked to BMP selection
- ensures consistency of water quality mitigative measures across the province
- accelerates approvals process by consistency of BMP selection process
- prevents unnecessary expenditure of money by selecting and designing BMPs based on specific water quality goals

9.6.2 BMP Design Manual Scope

A top down approach is recommended to ensure that watershed water quality goals/concerns drive the BMP selection process. As such, the manual must be applicable at the Watershed Plan, Master Drainage Plan, and Stormwater Management Plan stages. It is anticipated that very few watershed plans will be available for use by developer consultants. The majority of initial design manual applications will be made at the local stormwater management level. Therefore, the design manual must be able to refer to higher planning level sections at the stormwater management level to derive water quality concerns and downstream uses which ultimately drive the BMP selection process.

The selection of particular BMPs is not sufficient to ensure the protection of downstream water quality. Acceptable design principles are also required. For instance, a wet pond will not protect the downstream watercourse if the inlet is located adjacent to the outlet. The design manual must provide BMP design guidelines based on water quality concerns and constraints related to BMP orientation and location.

It is anticipated that BMP design guidelines will change with further research. It is reasonable to assume that BMP performance criteria, pollutant loading functions, and BMP applicability will also be subject to change with further research. Therefore, a key component of the design manual will be the ease with which it can be updated.

9.6.3 BMP Expert System (ES) Design Manual

The compilation of a design manual is a considerable undertaking since the integrated BMP plan will have to address local, instream, and watershed water quality concerns, flooding and erosion concerns, and groundwater management (recharge) and contamination concerns.

A "catalogue" style design manual will fulfil only part of what is needed. In addition, emphasis is needed on the design process. The use of an expert system will fulfil this additional requirement. In this respect, the use of an expert system is desirable since it would be user friendly and immediately usable by personnel with minimal computer experience. This is beneficial since bulky manuals tend to intimidate users from applying new techniques. There is a tendency to make a cursory review of large manuals for the sake of expediency. Unfortunately, this can result in the incorrect application of the manual techniques due to oversights of pertinent manual sections, or the lack of understanding with respect to underlying background assumptions.

An expert system, if designed correctly, can overcome these shortcomings, since the system would prevent the user from incorrectly applying BMP technology, and provide the user with preferred solutions based on best available technology. The dependency that a novice user may have on an expert system emphasizes the need for the rigorous development and testing of the system to ensure that it does not lead to solutions which indirectly affect other watershed attributes.

It is recommended that the expert system approach be utilized for the BMP design manual. As such, the use of the term "expert system" (ES) will be synonymous with the design manual in all subsequent sections.

9.6.4 Expert System Features

The primary goal of the expert system is the selection and sizing of a BMP(s) to address watershed quality/quantity and erosion concerns. It is recognized, however, that several other aspects of the system will have an impact on its acceptability and utility.

User Friendliness	The ES will be completely menu driven. General help screens will be provided to ensure that the user understands the type and significance of the information which is being requested. The use of hot keys and a mouse will be supported to speed up program application by the experienced user.
Graphical Capability	The ES should be visually attractive as well as functional to maintain user interest. Graphical representations of all BMPs will be provided to familiarize users with existing status quo BMPs. This is essential to provide key personnel who are not familiar with BMP design (eg. planners) with an understanding of how BMPs function.
Learning Capability	The ES will have the option to update the best available technology based on further research and monitoring. The system will be designed so that design guidelines, performance criteria, and pollutant loadings can be easily updated. An expert system is ideal for these types of updates as well as learning updates related to additional water quality concerns or goals.
Hardcopy Results	The ES will have an option to provide a hardcopy of the BMP selection/design process for any specific BMP design. This hardcopy could be included in design reports to assist reviewing agencies with their approval of specific BMP selections/designs.

9.6.5 BMP Expert System Components

The ES can effectively be discretized into two sections :

- planning/selection of a BMP plan
- design of individual BMPs

Both of these components are essential to the integration of water quality into current water resources planning and design practices. The selection of a BMP(s) can occur at all three stages of the planning process (Watershed Plan, Master Drainage Plan, Stormwater Management Plan) whereas the design of a BMP(s) would occur at either the Master Drainage Plan or Stormwater Management Plan. For the sake of simplicity regional BMP facilities can be treated as large local BMPs thereby restricting the design of BMPs solely to the Stormwater Management Plan level of the ES. It is appropriate to structure the ES based on the planning process since this provides a top down methodology for the selection and design of BMP facilities.

It must be recognized that the expert system cannot replace watershed planning. The compilation of the design manual (ES) will be an evolutionary process which will reflect the evolution of water quality control. As such, the ES will be designed from a qualitative rather than a quantitative perspective recognizing that while the qualitative aspects of water quality will remain stable (infiltration for baseflow augmentation, thermal mitigation for coldwater fisheries, peak flow frequency-duration reduction for erosion control) the quantitative aspects of BMP design (mm of infiltration for baseflow augmentation, distance of underground piping to reduce water temperature to 20 °C, peak flow reduction for different bank geometries and soil types) will be subject to change.

This type of qualitativeness will be prevalent at the Watershed and Master Drainage Plan levels.

Watershed Plan

In this section of the ES there are two objectives :

- the identification of water quality concerns/goals
- the identification of whether BMPs can address watershed goals

A) Water Quality Concerns

The ES system would have two options for the quantification of water quality concerns :

1) user input concerns from watershed planning
2) ES derived concerns from user responses

The water quality concerns or goals can be readily selected from a menu of concerns if the watershed plan has been completed since water quality concerns would have been identified during this study.

Unfortunately, these concerns will not be known if the watershed planning has not been implemented. If the watershed concerns have not been identified, the user would be required to meet with all of the regulatory agencies (MOE, MNR, CA, local municipality) to confirm the water quality concerns. These concerns could be directly input to the ES based on meetings with the agencies.

The ES will also be programmed to derive water quality concerns from a specific set of questions. The ES would be designed to ask questions regarding the watershed resources inventory and then determine water quality goals based on the responses. The user would still be responsible for confirming the ES derived water quality goals with the appropriate authorities.

B) BMPs versus Watershed Goals

The expert system will not have spatial capabilities since it is not planned to initially link the system to GIS. This means that although a user may identify baseflow augmentation as a concern, and that 50 % of the watershed soils are suitable for structural infiltration, the expert system will not know where the suitable soils are located with respect to the baseflow concerns. As such, the ES may allow the user to proceed with the selection of BMP solutions that may not satisfy the watershed concerns in all areas of the watershed. This is reasonable since it is not the intent of the expert system to replace watershed planning. The ES can only be used as an assistance tool at the planning stages. In this regard the ES may perform simplistic screening such as warning a user if baseflow augmentation was a concern and only 20 % of the soils were suitable for infiltration, but cannot be relied on as a substitute for watershed planning.

The ES would be designed to ask questions concerning watershed attributes and compare these to the watershed goals to determine whether the implementation of BMPs could achieve the specified goals.

The comparison between planned uses and water quality goals would be rudimentary. Although a detailed analysis would be beyond the scope of the ES, "rule of thumb" comparisons would be made such as the percentage of soils suitable for infiltration versus baseflow augmentation concerns.

This analysis, albeit cursory, would be an important aspect of the ES since it would identify inconsistencies between BMP implementation and watershed goals at an early stage before appreciable time and money are wasted.

Master Drainage Plan

Master Drainage Plans have two main objectives :

- selection of regional versus local BMPs
- specification of both regional and local BMP performance and non-compliance targets

The decision relating to regional versus local BMP solutions would be based on water quality concerns, importance of intermediate tributary reach water quality, land use, drainage area, recreational benefits, and maintenance costs.

The ES would be used to identify whether regional BMP facilities were compatible with the watershed water quality goals. If only some of the water quality concerns could be addressed by regional facilities the ES would identify which concerns would be addressed by regional facilities and which remaining concerns would have to be addressed by local BMP solutions.

Performance criteria affect the BMP design. As such, they are not specifically required until the stormwater management level. Their inclusion is required at the Master Drainage Plan level since different performance criteria may have to be set for local BMP solutions in different areas of the tributary depending on the homogeneity of the tributary characteristics. For example, if baseflow augmentation or groundwater recharge is one of the watershed concerns, a general review of the soils and aquifers must be made at the Master Drainage Plan to determine which areas are suitable for infiltration. If only 50% of the tributary area is conducive to structural infiltration, then infiltration performance targets must reflect this tributary restriction to ensure that the watershed goal for infiltration is met over the entire tributary area.

As in the Watershed Plan level the user would have several options regarding the specification of performance criteria. If a Master Drainage Plan has been completed the user would specify this and the ES would then skip directly to the Stormwater Management Plan level. The actual performance criteria would be specified at the SWM level.

If a Master Drainage Plan has not been completed then the user would be required to confirm performance criteria with the portion reviewing agencies. The ES would have the option of specifying performance criteria based on best available technology at the Stormwater Management Plan level. At the Master Drainage Plan level the ES would question the user concerning tributary homogeneity with respect to the physical characteristics of the tributary. The ES would use this information to modify the performance criteria at the Stormwater Management Plan level based on the specific physical characteristics of the local site. The ES generated performance criteria and possible cost sharing agreements for non-uniform tributary performance criteria must be confirmed with the appropriate reviewing agencies.

Stormwater Management Plan

Ideally, local BMPs are designed at the Stormwater Management Plan level according to water quality concerns identified in the Watershed Plan and performance criteria identified in the Master Drainage Plan. Realistically, the ES will have to use a subset of the Watershed and Master Drainage Plan questions to identify concerns and performance criteria for numerous stormwater management studies where neither a Watershed Plan nor a Master Drainage Plan has been completed. This is the only logical methodology since it is imperative that watershed water quality concerns drive the BMP and performance criteria selection. Unfortunately it will require that reviewing agencies and development consultants spend more time then they should identifying the premise for water quality control in areas where Watershed and Master Drainage Planning have not occurred.

This is a result of not implementing the existing planning process and is not a flaw in the BMP selection/design process.

The majority of emphasis in the design of the ES will be placed at the Stormwater Management Plan level. The following main tasks are proposed in the Stormwater Management Plan level of the ES:

- specification or calculation of performance criteria
- specification or calculation of design storage volumes
- identification of capital and annual maintenance costs
- specification of relevant BMP design guidelines

The specification of performance criteria would be based on responses from the Master Drainage Plan level of the ES. The ES would ask the user to directly input the performance criteria if a Master Drainage Plan had been completed or if the user had confirmed criteria with the reviewing agencies. Alternatively the ES could specify performance criteria based on the sensitivity of downstream receiving waters and water quality concerns. The ES could modify these criteria based on tributary restrictions identified in the Master Drainage Plan level of the ES (eg. infiltration volume would double for areas suitable for infiltration if only 50 % of the tributary area had suitable soils).

The ES would be designed to calculated storage volumes for water quality control based on land use, seasonality of water quality concern, type of BMP, and level of performance. These calculations would utilize generic curves comparable to those presented in Section 5. These curves would be calculated based on continuous simulation with various land uses. Several meteorological stations across Ontario would be used to compare regional differences between the resulting curves. There would be an option to utilize user input information such as the frequency and duration of runoff based on watershed modelling.

The flexibility in both the performance criteria and the hydrological relationships would be useful since it would allow individual conservation authorities and/or municipalities to provide local standards in terms of water quality parameters or performance criteria.

All current Watershed Plans require that a continuous simulation model of the watershed be assembled and calibrated as part of the terms of reference. The information from the modelling could be used by the ES to base the BMP design directly on the specific watershed results.

Once the final list of potential BMP solutions has been selected, the ES would calculate the approximate capital and annual maintenance costs based on the specified storage volume, land area, and user specified land costs. The ES would highlight the lowest costing solution but would reveal the costs for all of the final potential BMP solutions recognizing that the potential opportunities provided by some BMP solutions may outweigh their increase in cost.

The final function of the ES would be to specify design guidelines for the chosen BMP solution. Guidelines would be required to ensure the effectiveness of the BMPs that are implemented (prevention of short-circuiting, thermal stratification, re-suspension of sediments, etc). Guidelines would also be presented with respect to vegetation planting, aquatic vegetation, and the incorporation of buffer/filter strips. The ES would be capable of producing conceptual designs (eg. volume, depth, etc.) but would not produce actual detailed designs since local land constraints will influence BMP design.

The specification of an actual design would discourage consultants from providing new and innovative designs. In this respect the specification of ES derived storage volumes may also discourage the designer from trying new designs. This is a conflict which would have to be discussed with Ministry personnel before the design of the expert system. It may be prudent to specify suggested retention times for individual BMPs during specific seasons or target pollutant removal levels without providing target design volumes. A drawback of this scenario would be that the consultant would have to do considerably more work than is currently required in order to determine effective water quality storage volumes. It may also lead to greater difficulty in providing approvals. In this respect, the generic approach may provide a transitional solution to introduce water quality design, and could be replaced with more stringent design calculations in the future.

9.6.6 Supporting Documentation

It has been said that "the day the term 'paperless office' was invented was probably the best day to invest in a paper mill" (PC Magazine, 1990). The expert system will require hardcopy support since users will invariably want to review the decision tree process which drives the ES. The assumptions and background information which are used in the decision making process also need to be outlined both in the ES and on paper to ensure that the inherent assumptions are commensurate with the application of the ES.

The ES will be designed such that the supporting documentation does not have to be read before it can be applied. The supporting documentation will be written as supplemental material which shows how the ES makes decisions in the BMP selection/design process and not as a beginners guide to using the expert system. The supporting documentation will indicate what ES decision making parameters can be updated and what the impact would be if these parameters were changed.

9.6.7 Liability and Professional Responsibility

The expert system must be viewed as a selection/design tool aid. As such the availability of this tool does not relieve the designer from his/her professional responsibility to ensure that the BMP design is feasible, and satisfies all of the identified water quality concerns. Disclaimers to this effect would be prominently displayed in both the expert system and the supporting documentation.

9.6.8 BMP Design Manual Timing

It is imperative that the compilation of the design manual proceed as quickly as possible. Delays in its production will lead to increased diversification amongst reviewing agencies with respect to water quality design procedures and performance criteria, as well as increased frustration amongst developers and consulting engineers.

Figure 9.1 outlines the tasks required to compile the design manual and their estimated times for completion.

BMP DESIGN MANUAL (EXPERT SYSTEM) COMPILATION ONTARIO MINISTRY OF THE ENVIRONMENT								
TASK DESCRIPTION		SCHEDULE (Months)						
		1991						
		3	4	5	6	7	8	9
1.0	Watershed Plan Level							
1.1	Input Water Quality Concerns		■					
1.2	Derive Water Quality Concerns		■					
1.3	Review Watershed Resource Inventory		■					
1.4	Prioritize Water Quality Concerns		■					
1.5	Compare Land Use to Water Quality Goals		■					
2.0	Master Drainage Plan Level							
2.1	Select Long List of Potential BMPs		■					
2.2	Identify Regional Issues		■					
2.3	Identify Potential Regional BMPs			■				
2.4	Identify Tributary Physical Restrictions			■				
3.0	Stormwater Management Plan Level							
3.1	Input BMP Performance Criteria			■				
3.2	Derive BMP Performance Criteria			■				
3.3	Modify Criteria based on MDP Restrictions			■				
3.4	Screen Out Physically Infeasible BMPs			■				
3.5	Prioritize Remaining BMPs				■			
3.6	Identify Potential Opportunities				■			
3.7	Screen Out Redundant BMPs				■			
3.8	Select Pre-Design Set of BMPs				■			
3.9	Size Remaining BMPs				■			
3.10	Calculate Capital and Maintenance Costs				■			
3.11	Select BMP Solution				■			
3.12	Specify Design Guidelines					■		
3.13	Identify any Remaining Concerns					■		
4.0	Expert System Features							
4.1	Development of On-Line Help		■	■	■	■		
4.2	ES Graphical Interface		■	■				
4.3	Analysis of Meteorological Stations		■	■				
4.4	Analysis of Groundwater Requirements		■	■				
4.5	Development of Performance Criteria		■	■				
4.6	Development of Design Guidelines		■	■	■			
5.0	Project Management							
5.1	Project Start-up Meeting		■					
5.2	Project Meetings			■	■	■		
5.3	Preparation of Users Manual					■		
5.4	Final Presentation of Expert System						■	
5.5	Public Sector Seminars							■
5.6	Private Sector Seminars							■

Note: TECH/SUPP indicates TECHnician, drafting, clerical and other SUPPort staff

Figure 9.1 Best Management Practices Design Manual (Expert System) Schedule

REFERENCES

Adams, L.W., T.M. Franklin, L.E. Dove and J.M. Duffield, 1986. Design considerations for wildlife in urban stormwater management. pp. 249-259, In R.F. McCabe [ed.]. Transactions of the 51st North American Wildlife and Natural Resource Conference, March 21-26, 1984. Reno, Nevada.

Adams, L.W., L.E. Dove and D.L. Leedy, 1984. Public attitudes toward urban wetlands for stormwater control and wildlife enhancement. Wildlife Society Bulletin, Vol 12:299-303.

Alexander, G.R., and E.A. Hansen, 1988. Decline and recovery of a brook trout stream following an experimental addition of sand sediment. Michigan Department of Natural Resources, Fisheries Research Report No. 1943.

American Public Works Association, 1981. Urban Water Management. Water Resources Special Report #49, Chicago, Illinois, 295 pp.

Bayley, S.E.; Behr, R.S. and C.A. Kelly, 1986. Retention and release of sulphur from a freshwater wetland, In: Water, air, and soil pollution, Vol 31:101-114.

Baxter, E., G. Mulamoottil and D. Gregor, 1985. A study of residential stormwater impoundments: Perception and Policy Implications. Water Resources Bulletin, Vol 21(1):83-88.

Comeau, A. and P. Wisner, 1989. Critical notes on the use of storage ponds for runoff quality control. Paul Wisner and Associates Inc.

Chan, E., T.A. Bursztynsky, N. Hantzche and Y.J. Litwin, 1981. The use of wetlands for water pollution control. Municipal Environmental Research Laboratory, U.S. Environment Protection Agency, Report S2-82-086.

Colston, N.V., 1974. Characterization and treatment of urban land runoff. U.S. Environmental Protection Agency, Washington, D.C. EPA-670/2-74-096.

Cummins, K.W., G.W. Minshall, J.R. Sedell, C.E. Cushing, and R.C. Petersen, 1984. Stream ecosystem theory. Verhandlung International Vereingung Limnologie. 22:1818-1827.

De Fillipi, J.A. and C.S. Shih, 1971. Characteristics of separated and combined sewer flows. J. Water Pollution Control Federation, 43(10).

Dietemann, A.J., 1975. A provisional inventory of the fishes of Rock Creek, Little Falls, Cabin John Creek and Rock Run, Montgomery County, Maryland. Report prepared for the Maryland National Capital Park and Planning Commission, Silver Spring, Maryland , 40pp.

Dillaha, T.A., J.H. Shepard and D. Lee, 1986. Long Term Effectiveness and Maintenance of Vegetated Filter Strips. Virginia Water Resources Research Centre. Bulletin #153 Blacksburg, VA.

Driscoll, E.D., 1983. Evaluation of Urban Non-Point Remedial Measures. E.D. Driscoll and Associates, Oakland, New Jersey.

Driscoll, E.D., 1986. Lognormality of point and nonpoint source pollutant concentration,in Urban runoff Quality: Impact and Quality Enhancement Technology, (eds., B. Urbonas and L.D. Roester). Engineering Foundation and American Society of Civil Engineers, New York, NY, 458-459.

Driscoll, E.D., 1988. Long term performance of water quality ponds, in Design of Urban Runoff Quality Controls, (eds., L. Roesner, B. Urbonas and M. Sonnen). Engineering Foundation and American Society of Civil Engineers, New York, NY.

Ferrara, R.A and P. Witkowski, 1983. Stormwater Quality Characteristics in Detention Basins. Journal of Environmental Engineering, American Society of Civil Engineers, Vol. 109(2):428-447.

Field, R., H. Masters and M. Singer, 1982. Status of Porous Pavement Research, Water Resources Research 16:849-858.

Free, B.M. and G.G. Mulamoottil. 1983. The limnology of Lake Wabukayne, a storm-water impoundment. Water Resources Bulletin, 19(5):821-827.

Gemza, A.S and G.W. Robinson, 1989. Urban lake water quality assessment, Lake Aquitaine and Lake Wabukayne, Data report summary the year 1977-1986. Ontario Ministry of the Environment, Water Resources Branch, Biology Section.

Gietz, R. J., 1983. Rideau River Stormwater Management Study - Urban Runoff Treatment in Kennedy-Burnett Settling Pond, Regional Municipality of Ottawa-Carleton

Gietz, R.J., 1981. Stormwater Runoff Treatment by Impoundment (Barrhaven Pilot Study), Canadian Mortgage Housing Corporation, Environment Canada

Government of Ontario et al., 1987. Guidelines on erosion and sediment control for urban construction sites, M.N.R and M.O.E., M.M.A., M.T.O. & M.T.C., Conser. Auth., Munic. Eng. Ass. & U.D.I.

Government of Ontario et al., 1987. Urban Drainage Design Guidelines, M.N.R and M.O.E., M.M.A., M.T.O. & M.T.C., Conser. Auth., Munic. Eng. Ass. & U.D.I.

Grizzard, T.J., C.W. Randall, B.L. Weand and K.L. Ellis, 1986. Effectiveness of extended detention ponds, in Urban Runoff Quality, (eds., B. Urbonas and L. Roesner). Engineering Foundation and American Society of Civil Engineers, New York, N.Y, 323-337.

Hammer, D.A. 1989. Constructed wetlands for wastewater treatment: an overview of emerging technology. Presented at the "Urban Stream Corridor and Stormwater Management Symposium, March 14-16, 1989, Colorado Springs, Colorado.

Hammer, D.A. [ed.]. 1990. Constructed Wetlands for Wastewater Treatment. Lewis Publishers. 831 p.

Hansen, C.A., M.K. Gupta, and R.W. Agnew. 1973. Two Wisconsin cities treat combined sewer outflows. Water and Sewage Works. 120(8).

Harrington, B., 1988. Design and Construction of Infiltration Trenches, in Design of Urban Runoff Quality Controls, (eds., L. Roesner, B. Urbonas and M. Sonnen). Engineering Foundation and American Society of Civil Engineers, New York, NY.

Harper, H.H., et al. 1986. Stormwater treatment by natural systems. Report submitted to the Florida Department of Environmental Regulation.

Hartigan, J.P., 1986. Regional BMP Master Plans, in Urban Runoff Quality, (eds., B. Urbonas and L. Roesner). American Society of Civil Engineers , New York, NY.

Hartigan, J.P., 1988. Basis for design of wet detention basis BMP's, in Design of Urban Runoff Quality Controls, (eds., L. Roesner, B. Urbonas and M. Sonnen). Engineering Foundation and American Society of Civil Engineers, New York, NY.

Holling, C.S. (ed.). 1878. Adaptive environmental assessment and management. John Wiley and Sons. Chichester. 377 p.

Imhof, J. 1990. Watersheds, streams and stormwater management. p. 6-8. In D. Featherstone [ed]. Proceedings of the Stormwater Infiltration Workshop. American Fisheries Society, Southern Ontario Chapter.

Jones, D.E., 1988. Summary of institutional issues, in Design of Urban Runoff Quality Controls, (eds., L. Roesner, B. Urbonas and M. Sonnen). Engineering Foundation and American Society of Civil Engineers, New York, NY.

Jones, R.C., and G.W. Redfield. 1984. Effects of urban stormwater runoff on reservoir phytoplankton. Verhandlung International Vereingung Limnologie, 22:1486-1492.

Kelcey, J.G., 1978. Techniques No. 31: Creative Ecology Part 2, Selected Aquatic Habitats, Landscape Design. Vol. 121(2):36-38.

Kellerher, M., 1989. Experimental UV Project at London's Fanshawe Beach. Environmental Science and Engineering.

Kerkmann, R., 1990. Lake Aquitane Sediment Removal (Draft). City of Missisauga.

Klein, R.D. and J.D. Gracie, 1980. An Integrated Watershed Management Policy. Maryland Department of Natural Resources and Maryland Chapter - Trout Unlimited.

Klein, R.D., 1979. Urbanization and stream quality impairment. Water Resources Bulletin, 15(4):948-963.

Korsiak, T. and G. Mulamoottil, 1986. Stormwater Management Measures in Ontario : Status and Problems in Implementation. Canadian Water Resources Journal Vol. 11(4):5-15.

Kutash, W., 1985. Effectiveness of wetland stormwater treatment - some examples. p. 145-157, in Stormwater Management: An Update. University of Central Florida Environmental Systems Engineering Institute Publication 85-1. Orlando, FL.

Lakatos, D.F. and L.J. McNemar, 1986. Stormwater quality management using wetlands. Presented at Freshwater Wetlands and Wildlife Symposium. Charleston, SC.

Leopold, L.B. 1968. Hydrology for urban planning - a guidebook on the hydrologic effect of urban land use. Circular 554, U.S. Geological Survey, Washington, D.C.

Livingston, H.E., 1988. Stormwater regulatory program in Florida, in Design of Urban Runoff Quality, (eds., L. Roesner, B. Urbonas and M. Sonnen). Engineering Foundation and American Society of Civil Engineers, New York, NY.

Livingston, E.H. 1990. Use of wetlands for urban stormwater management. p. 253-262, in D.A. Hammer [ed.]. Constructed Wetlands for Wastewater Treatment. Lewis Publishers. 831 p.

Martin, E.H., 1988. Mixing and residence time of stormwater runoff in a detention system, in Design of Urban Runoff Quality Controls, (eds., L. Roesner, B. Urbonas and M. Sonnen). Engineering Foundation and American Society of Civil Engineers, New York, NY.

Marsalek, J., 1986. Report on NATO workshop on urban runoff quality. Environment Canada, National Water Research Institute, Burlington.

Marshall Macklin Monaghan Limited and Beak Consultants, 1988, The Rouge River Urban Drainage Study

Maryland Water Resources Administration, 1986a. Maintenance of stormwater management structures: A Department Summary. Sediment and Stormwater Division, Maryland Department of Natural Resources, Annapolis, Maryland, 33p.

Maryland Water Resources Administration, 1986b. Minimum water quality and planning guidelines for infiltration practices. Maryland Department of Natural Resources, Annapolis, Maryland, 52p.

Maryland Water Resources Administration, 1986c. Feasibility and design of wet ponds to achieve water quality control. Sediment and Stormwater Division, Maryland Department of Natural Resources, Annapolis, Maryland, 32p.

Metro Toronto Remedial Action Plan (RAP), 1990. Draft Discussion Paper on Remedial Options.

McCuen, R., and G. Moglen, 1988. Multicriterion Stormwater Management Methods. Journal of Water Resources Planning and Management, American Society of Civil Engineers, Vol. 114(4):414-431.

Michaels, S., E.A. McBean and G. Mulamoottil, 1985. Canadian Stormwater Impoundment Experience, Canadian Water Resources Journal, Vol 10(2):46-55.
Miller. R.A, 1985. Percentage entrainment of constituent loads in urban runoff, South Florida. United States Geological Survey, WRI 84-4319.

Minnesota Pollution Control Agency, 1989. Protecting Water Quality in Urban Areas. Division of Water Quality.

Moore, K.W., 1978. Urban Drainage Practices in Canada. Environment Canada, Ontario Ministry of Environment, Agreement on Great Lakes Water Quality, Conference #5.

Mulamoottil, G., 1977. Urban Lakes and the Problems Consulting Engineers may encounter, in Canadian Consulting Engineer

Murphy, C.B., D.A. MacArthur, D.J. Carleo, 1981. Best Management Practices Implementation. U.S Environmental Protection Agency, Rochester, NY, Report 905/9/81/002.

Nix, S., 1985. Residence time in stormwater detention basins. Journal of Environmental Engineering, American Society of Civil Engineers, Vol. 3(1).

Nix, S. and J.P. Heaney, 1988. Optimization of Stormwater Storages Release Strategies. Water Resources Research, American Geographical Union, paper #88WR03409.

Nix, S., 1988. Suspended solids removal in detention basins. Journal of Environmental Engineering, American Society of Civil Engineers, Vol. 116(6).

Novotny, V., H. Sung, R. Bannerman and K. Baum, 1985. Estimating nonpoint pollution from small urban watersheds. Journal Water Pollution Control Federation, Vol. 57(4):339-347.

Oberts, G.L., 1982. Water resources management: Nonpoint source pollution technical report. U.S. Geological Survey, Reston, VA.-Metropolitant Council, St. Paul, NIN.

Ontario Ministry of Environment, Ministry of Natural Resources, 1989. Interim Stormwater Quality Control Guidelines for New Development (Draft).

Pitt, R., 1985. Urban runoff control manual of practice for use with the source loading and management model. Ontario Ministry of the Environment.

Planck, R.J. 1990. Stormwater infiltration techniques in Southern Ontario. p. 31-38. In D. Featherstone [ed]. Proceedings of the Stormwater Infiltration Workshop. American Fisheries Society, Southern Ontario Chapter.

Pluhowski, E.J. 1970. Urbanization and its effects on the temperature of streams on Long Island, New York. U.S. Geological Survey Professional Paper 627-D.

Qureshi, A.A. and B.J. Dutka. 1979. Microbiological studies on the quality of urban stormwater runoff in southern Ontario, Canada. Water Research 13:977-985.

Ragan, R.M and A.J. Dietemann, 1976. Characterization of urban runoff in the Maryland suburbs of Washington DC. Technical Report 38, Water Resources Research Centre, University of Maryland, College Park, Maryland, 135p.

Randall, C.W., 1982. Stormwater detention ponds for water quality control, proc. of the conference on Stormwater Detention Facilities (ed. W. DeGroot). Engineering Foundation and the American Society of Civil Engineers.

Randall, C.W., K. Ellis, T.J. Grizzard and W.R . Knocke, 1982. Urban runoff pollutant removal by sedimentation, proc. of the conference on Stormwater Detention Facilities (ed. W. DeGroot). Engineering Foundation and the American Society of Civil Engineers.

Regional Municipality of Ottawa-Carleton, Works Department, Pollution Control Division, 1979. Stormwater Runoff Treatment by Impoundment (Barrhaven Pilot Study)

Rippey, I. and B. Rippey, 1986. Chemical limnology of two artificial lakes used for both stormwater management and recreation. Hydrobiologia 139:201-235.

Roesner, L.A., 1988. Conference overview and summary, in Design of Urban Runoff Quality Controls, (eds., L. Roesner, B. Urbonas and M. Sonnen). Engineering Foundation and American Society of Civil Engineers, New York, NY.

Roesner, L.A. and R. Shogren, 1990. Creating a 100-year living master plan for Cincinnatti's combined sewer system. Waterworld News.

Roulet, N.T.; Woo, M.K., 1986. Hydrology of a Wetland in the Continuous Permafrost Region, in: Journal of Hydrology.

Rowney, A.C., R.L. Droste, and C.R. MacRae. 1986. Sediment and ecosystem characteristics of a detention lake receiving urban runoff. Water Pollution Research Journal Canada, Vol. 21(6):460-473.

Salo, J.E., D. Harrison and E.M. Archibald, 1986. Removing contaminants by Groundwater Recharge Basins. Journal American Waterworks Association.

Sartor, J.D., G.B. Boyd and F.J. Agardy. 1974. Water pollution aspects of street surface contaminants. Journal Water Pollution Control Federation, Vol. 46:458-467.

Schueler, T.R., R. Magill, M.P. Sullivan and C. Wiegand, 1985. Comparative Pollutant Removal Capability: Economics and Physical Suitability of Urban BMPs in the Washington Metropolitan Area. International Symposium on Nonpoint Source Pollutant Abatement, Marquette University, Milwaukee, WI, p. 416-422.

Schueler, T.R., 1987. Controlling Urban Runoff: A Practical Manual for Planning and Design of Urban BMP's, Metropolitan Washington Council of Governments

Science Applications International Corporation, 1987. Draft report on Best Management Practices for the Control of Stormwater from Urbanized Areas, Prepared for U.S. E.P.A., Office of Water Enforcement and Permits.

Shaheen, D.G. 1975. Contributions of urban roadway usage to water pollution. U.S. Environmental Protection Agency, Washington, D.C. EPA 600/1-75-004.

Shaver, H.E., 1986. Infiltration as a Stormwater Management Component, in Urban Runoff Quality: Impact & Quality Enhancement Technology, (eds., B. Urbonas and L. Roesner). Engineering Foundation and American Society of Civil Engineers (ASCE), New York, N.Y.

Shaver, H.E., 1988. Institutional stormwater management issues, in Design of Urban Runoff Quality Controls, (eds., L. Roesner, B. Urbonas and M. Sonnen). Engineering Foundation and American Society of Civil Engineers, New York, NY.

State of Maryland Department of the Environment, 1984. Standards and specifications for Infiltration Practices. Sediment and Stormwater Administration.

State of Maryland Department of the Environment, undated. Wetland Basins for Stormwater Treatment. Sediment and Stormwater Administration.

Stenstrom, M.K., G.S. Herman & T.A. Burstynsky, 1984. Oil and Grease in Urban Stormwater. Journal of Environmental Engineering, American Society of Civil Engineers, Vol 110 (1):58-72.

Stockdale, E.C. 1986a. The use of wetlands for stormwater management and nonpoint pollution control: a review of the literature. Report submitted to the Washington State Department of Ecology.

Stockdale, E.C. 1986b. Viability of freshwater wetlands for urban surface water management and nonpoint pollution control: an annotated bibliography. Report submitted to the Washington State Department of Ecology.

Swinnerton, G.S. and T.D. Hinch, 1987. The Recreation Function of Beaumaris Stormwater Lake. Canadian Water Resources Journal.

Tollner, E.N., B.J. Barfield and J.C. Hayes, 1982. Sedimentology of Erect Vegetal Filters, Proceedings Hydraulics Division, American Society of Civil Engineers, Vol. 108(12):1518-1531.

Urbonas, B. and W.P. Ruzzo, 1986. Standardization of Detention Pond Design for Phosphorus Removal, in Urban Runoff Control, (eds., H. Torno, J. Marsalek and M. Desbordes). Springer Verlag (ISBN-3-540-16090-6):739-760.

U.S. Environmental Protection Agency (EPA), 1983. Final Report of the Nationwide Urban Runoff Program. Water Planning Division. Washington, DC.

U.S. Environmental Protection Agency (EPA), 1986. Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality, Nonpoint Source Branch. Office of Water, Washington, D.C.

U.S. Environmental Protection Agency, 1987. Guide to Nonpoint Source Pollution Control. Office of Water, Washington DC. 20460.

Walker, W.W., 1987. Phosphorus removal by urban runoff detention basins. Lake And Reservoir Management. 3:314-326.

Waller, D.H., 1978. Urban drainage problems - an overview. p. 13-32. in Modern concepts in urban drainage. Conference Proceedings No. 5., Research Program for the Abatement of Municipal Pollution Under Provisions of the Canada-Ontario Agreement on Great Lakes Water Quality. Environment Canada and Ontario Ministry of the Environment.

Warren, C.E., 1971. Biology and Water Pollution Control. W.B. Saunders Company, 434p.

Weatherbe, D., J. Marsalek and G. Zukovs, 1982. Research and Practice in Urban Runoff in Canada. American Society of Civil Engineers, New York, NY.

Weibel, S., R. Angerson, and R.L. Woodward, 1964. Urban land runoff as a factor in stream pollution. Journal Water Pollution Control Federation, Vol. 36(7):914-924.

Whipple, W., 1979. Dual-Purpose Detention Basins. Journal of the Water Resources Planning and Management Division, American Society of Civil Engineers, New York, NY, Vol 105:403-412.

Whipple, W. and J.V. Hunter, 1981. Settleability of Urban Runoff Pollution, Journal Water Pollution Control Federation. 53(1): 1726-1732.

Wiegand, C., Schueler, T., Chittenden, W. and D. Jellick, 1986. Cost of Urban Runoff Controls, in Urban Runoff Quality: Impact and Quality Enhancement Technology, (eds., B. Urbonas and L. Roesner). Engineering Foundation and American Society of Civil Engineers (ASCE), New York, NY.

Wigginton, P.J., C.W. Randall and T.J. Grizzard, 1986. Accumulation of selected trace metals in soils of urban runoff swale drains. Water Resources Bulletin, Vol 22(1):73-79.

Wilber, W.G. and J.V. Hunter, 1975. Heavy metals in urban runoff. pp. 217-238 In Nonpoint Sources of Water Pollution. Virginia Water Resources Research Centre, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Wulliman, J.T., M. Maxwell, W.E. Wenk and B. Urbonas, 1988. Multiple treatment system for phosphorus removal, in Design of Urban Runoff Quality Controls, (eds., L. Roesner, B. Urbonas and M. Sonnen). Engineering Foundation and American Society of Civil Engineers, New York, NY.

Zinger, I. and C.E. Delisle, 1988. Quality of used-snow discharged in the St-Lawrence River (in the region of Montreal Harbour), Water, air and soil pollution

STORMWATER QUALITY BEST MANAGEMENT PRACTICES

APPENDICES

It should be recognized that some of the material in the Appendices was presented in an earlier interim report. As such, the numbering of sections in the appendices refers to the order of the earlier document and not to the appendices themselves. The page numbering has been revised to reflect the individual appendices.

Appendix A

GLOSSARY

This appendix provides definitions of frequently used terms in the main report. Illustrations are also provided (Schueler, 1987) to aid in the visualization of different BMP types.

Artificial Wetlands	An artificial wetland is created by maintaining the water level at the surface of the ground. Water can either be conveyed to the surface of the wetland or through a subsurface layer of gravel or sand (Vegetated Submerged Bed). Wetlands usually contain vegetation such as rushes, reeds, and/or cattails.
BMP	Best Management Practice
Conservation	Conservation involves retaining a portion of the land in its natural condition (undeveloped).
Downzoning	Downzoning is a process whereby the proposed level of imperviousness of development in a certain area is lowered (industrial (high imperviousness) to estate residential (low imperviousness)) recognizing the environmental sensitivity of the development area.
Ecosystem Approach	The ecosystem approach is an approach to development which takes into account the air, land, water, and living organisms, including humans, and the interactions among them. It can be applied at varying scales of magnitude (global, basin, watershed, master drainage plan, stormwater management plan)
Extended Detention Pond	An extended detention pond may be either wet or dry. An extended detention pond consists of a low flow device which drains small storms or the first flush of larger storms. The low flow device typically extends the duration of detention of small storms to times between 24 and 48 hours.

Grassed Swales	Grassed swales are drainage ditches lined with either grass or other vegetation which convey stormwater from the developed area to the storm sewer or watercourse.
Infiltration Basin	An infiltration basin is essentially a dry detention pond without an outlet. All of the stormwater (or up to a specified return period) infiltrates into the ground. Infiltration basins are routinely tile drained to help mitigate clogging problems and long term standing water.
Infiltration Trench	An infiltration trench conveys stormwater through clean gravel to a filter material (usually sand or peat-sand). Runoff exfiltrates through the sand filter and recharges the groundwater.
Master Drainage Plan	Master Drainage Plans (MDP) are usually environmental plans prepared for the management of river tributary ecosystems under future development conditions. As such, the MDP is prepared for a sub-area of the watershed. Traditionally, Master Drainage Plans have only been concerned with water quantity. Currently, Master Drainage Plans take into account both water quantity and quality, and in some instances the entire tributary ecosystem.
Oil/Grit Separator	An oil/grit separator, or water quality inlet, has compartments (typically 3) specifically designed to trap sediment, and separate oil and grease from the stormwater. These separators can be used on their own, or as pretreatment devices for other BMPs.
Porous Pavement	Porous pavement is pavement which allows the infiltration of water. Typically, porous pavement is composed of an ordinary aggregate mixture with the exclusion of fine particles. Water migrates through the open pore spaces in the pavement and is collected in a sub-surface gravel reservoir. The water recharges the groundwater until the reservoir is full. Once the reservoir is full the excess water is conveyed by perforated pipes to the regular storm sewer system.

Receiving Waters	The receiving waters refers to the watercourse network into which stormwater is conveyed from the development.
Riser	An outlet consisting of a vertical outlet pipe into which holes have been drilled and/or a weir has been installed.
Seepage Trench	A seepage trench is usually an infiltration trench designed specifically to receive water from the roofs of buildings.
Storage Tanks	Storage tanks are simply large underground tanks used to detain stormwater. Storage tanks are very expensive, and are usually only used in areas where land is at an absolute premium.
Stormwater Management Plan	A stormwater management plan is a water management plan prepared for a specific area within the Master Drainage Plan area. Historically, stormwater management plans have only been concerned with water quantity. Currently, stormwater management plans consider water quantity and quality, and in some instances, habitat.
Stormwater Utility	An independent organization (public or private) which collects funds from individual users (homeowners, corporations) of stormwater facilities. A "user" may be defined as any person(s) owning property which drains to the facility.
Vegetated Buffer Strips	Vegetated buffer strips are sections of vegetated land which separate development areas from streams/creeks/swales.
Vegetated Filter Strip	Vegetated filter strips usually incorporate a level spreader which spreads concentrated flow from a sewer or swale over a vegetated area of land (turns rill flow into sheet flow).
Watershed	In its literal sense watershed refers to the drainage boundary of a river system. Commonly, as in this report, watershed refers to the area within the drainage boundary also.

Watershed Plan	A Watershed Plan is a planning document prepared to ensure that future development proceeds in a manner which protects the environmental resources in the watershed. Traditionally, watershed plans have only been concerned with water quantity. Current watershed plans take an ecosystem approach in planning development whereby the interactions of all living organisms and resources are taken into account.
Wet Pond	A wet pond, or retention pond, contains a permanent pool of stormwater which does not drain after a storm.

Figure 3.1: Schematic of a Dry Extended Detention Pond

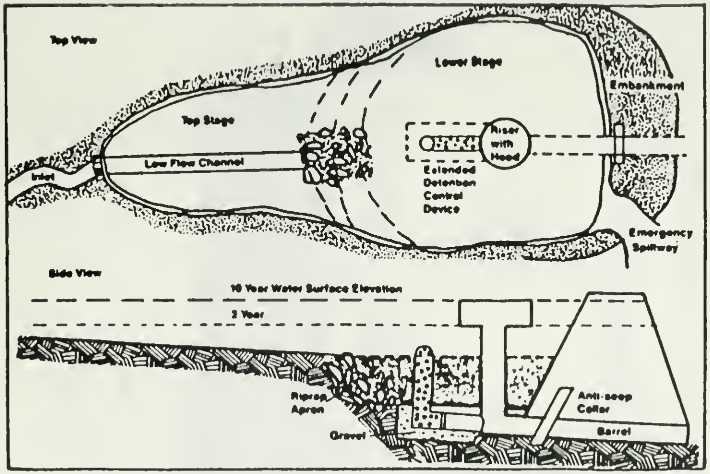


Figure 4.1: Schematic of a Wet Pond

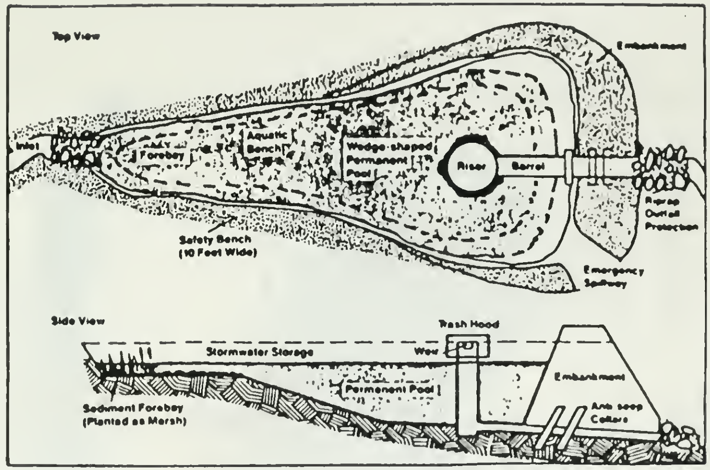


Figure 5.1: Schematic of an Infiltration Trench

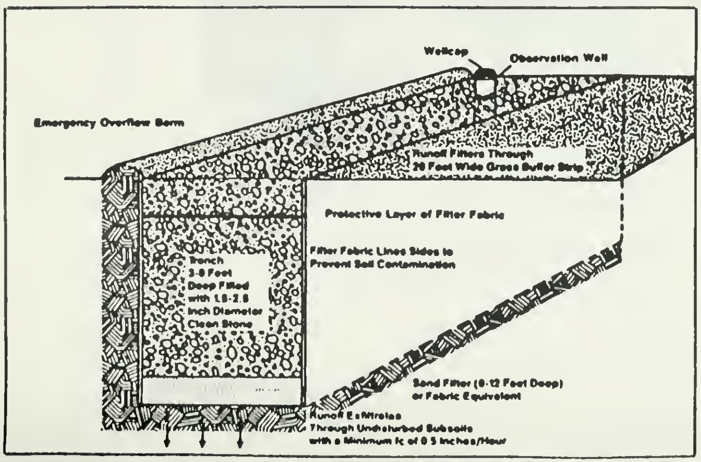


Figure 8.1: Schematic of a Water Quality Inlet, Montgomery County, MD. Three Chamber Design

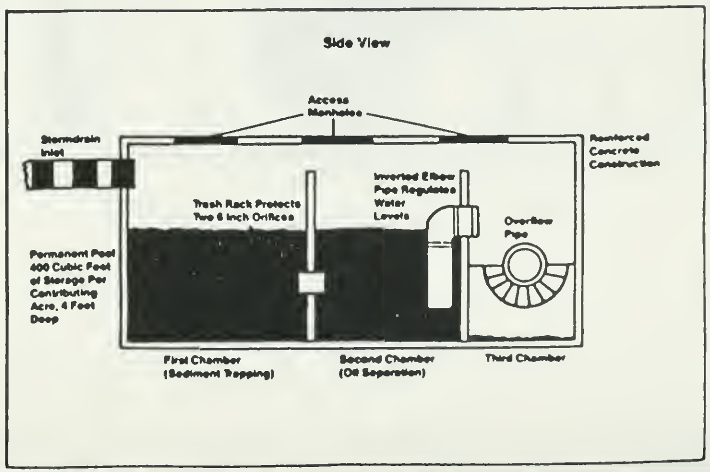


Figure 6.1: Schematic of an Infiltration Basin

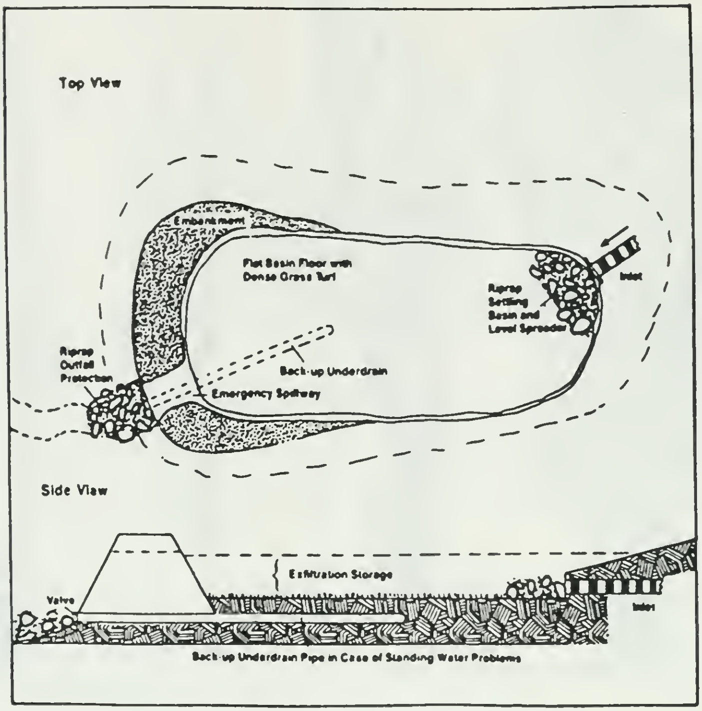


Figure 7.6: Design Schematic for Porous Pavement

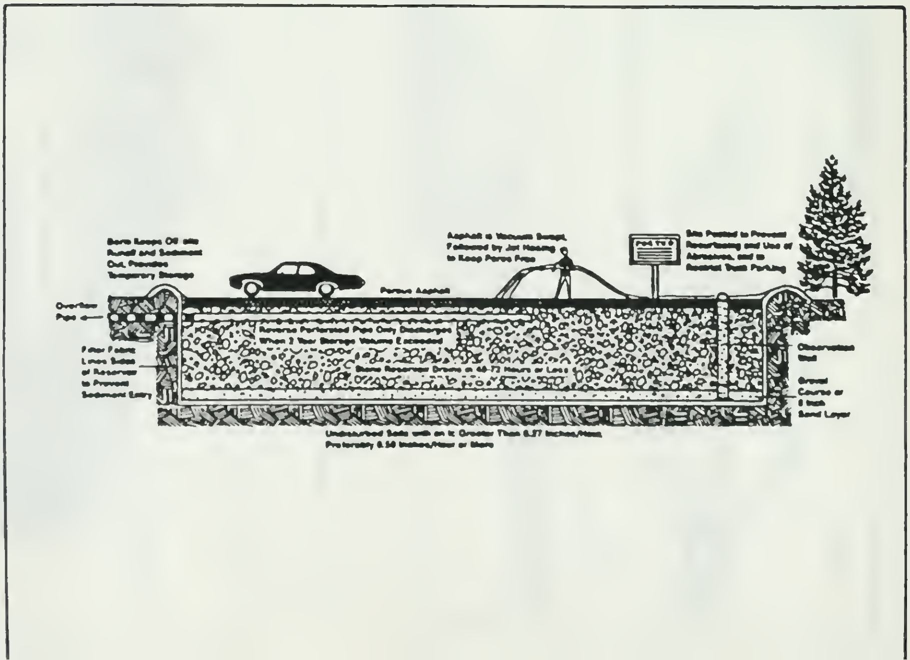


Figure 9.3: Schematic of a Filter Strip

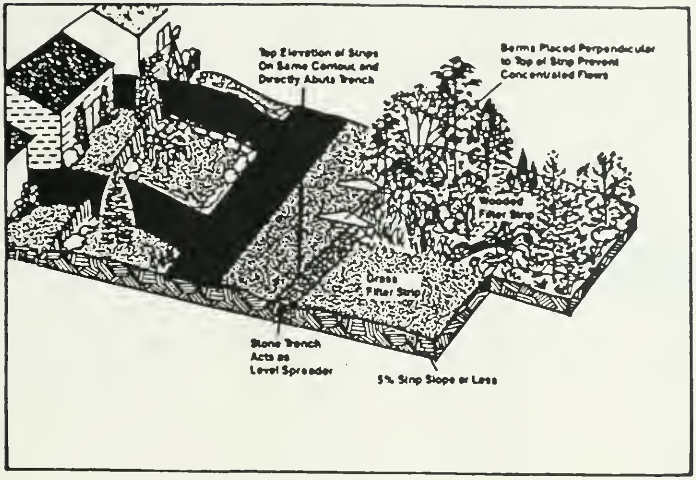
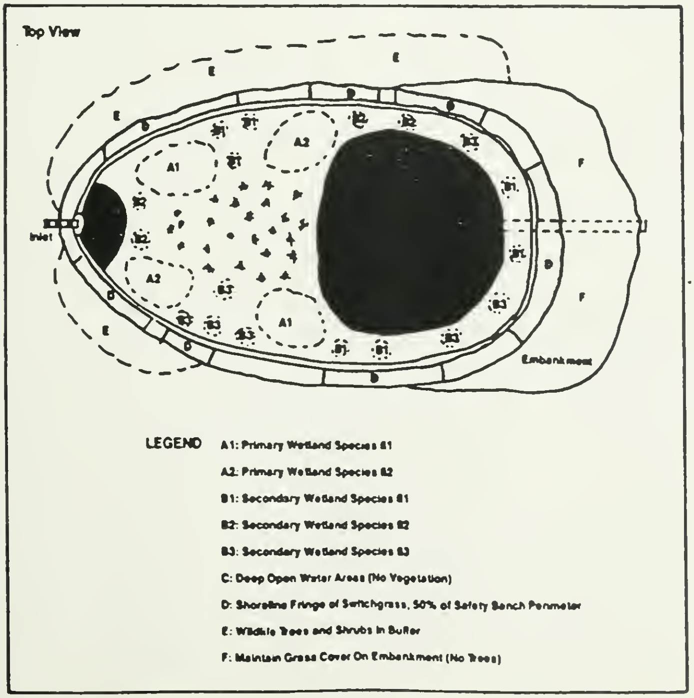


Figure 9.5: Examples of Shallow Marsh Planting Strategies



Appendix B

4.0 SUMMARY OF REMOVAL EFFICIENCIES IN THE LITERATURE

A summary of BMP pollutant removal rates from the monitoring data, and literature is provided in Table 4.1.

Table 4.1 shows the variation in effectiveness with the different guidelines for BMP design and operation.

A comparison of removal rates between field results and laboratory experiments indicates that the laboratory results are usually optimistic in the estimation of pollutant removal capability.

BMP Average Removal Rates (% reduction)											
BMP	Author	SS	P	N	COD	Zn	Pb	Fecal Coliform	Retention Time (hr)	Field , Lab or Modelling	Design
Extended Detention	OWML (1983)	90	50	40	50	45	85		48	Lab	
Extended Detention	NURP (1983)	64	15	1	30	57	84		48	Field	
Dry Pond	Biggers (1980)	14	10	20							
Dry Pond (Stedwick)	Randall (1982)	77	26	0						Field	
Dry Pond (Lakeridge)	MWCOG (1983)	14	20	10	0	0				Field	2 Year SWM
Wet Pond	Ferrara (1983)	32	17	0	14					Field	
Wet Pond	Biggers (1980)	55	28	66	22*						
Wet Ponds (Burke) **	Randall (1982)	37	59	37						Field	
Wet Pond (Westleigh)**	Randall (1982)	87	70	46						Field	
Wet Pond	EPA (1986)	75	52	42	40*	40	70				
Wet Pond	Whipple (1981)	68	50		40*	30	65		32	Lab	
Wet Pond	Randall (1982)	90	56	33	45	44	86		48	Lab	
Wet Ponds (9)	NURP (1983)	59	35	25	24	27	71			Field	
Wet Pond	Pitt (1985)	85				53	87				
Wet Pond (Uplands)	MMM (1990)	79	45					93	63	Field	pond=1% area
Wet Pond (Borden Farm)	MMM (1990)	59	48					69	48	Field	25 mm - 72 hr
Wet Pond (Barrhaven)	MMM (1990)	52	47					56	75	Field	25 mm - 72 hr
Wet Pond (Merivale)	MMM (1990)	83	46					67		Field	# overflows/y
Wet Pond (Hunt Club R.)	MMM (1990)	90	63							Field	
Wet Pond(Kennedy-Burn.)	RMOC (1983) batch	98	79	54	36*	21	39			Field	
Wet Pond(Kennedy-Burn.)	RMOC (1983) cont.	93	86	57	57					Field	
Wet Pond (L. Aquitaine)	MOE (1989)	65	77	47					7896	Field	
Wet Pond (L. Wabukayne)	MOE (1989)	0	25	0					312	Field	
Extended Dry Pond	MWCOG (1983)	70	13	24	27	57	62		12	Field	
Extended Dry Pond	Grizzard (1988)	74	56	60	41	40	24		12	Field	
Extended Dry Pond	Stack (1988)	73	35						18	Field	
Extended Dry Pond	MWCOG (1983)	85	50	39	54				48	Lab	
Extended Wet Pond	USEPA (1983)	91	27	42	42*						
Infiltration Basins	MWCOG (1987)	99	70	65	90*						
Infiltration Trench	USEPA (1983)	96	41	61	84*						
Infiltration Trench	MWCOG (1987)	99	70	67	90*						
Porous Pavement	USEPA (1983)	96	41	61	84*						
Porous Pavement	OWML (1986) MWCOG	89	65	82	82	99	98				
Oil/Grit Separator	Pitt (1984)	18	10	10							
Oil/Grit Separator	MWCOG (1987)	30									
Grassed Swales	Metcalf (1980)	89	0	16	38*						
Grassed Swales	NURP (1983)				25	50	59				
Street Sweeping (3x/wk)	Sutherland (1978)	70								Modelling	
Street Sweeping (1x/wk)	Novotny (1985)	15								Field + Model	
Street Sweeping (3x/wk)	Pitt (1985)	3				3	9				
Catch-basin cleaning	Pitt (1985)	15				8	15				
Wet Pond + Wetland	Martin (1988)	55	43	36		70	83			Field	
U.V. Disin. (Barrhaven)	MMM (1990)							94		Field (Pilot)	

* BOD

** Part of NURP Study

Table 4.1 Summary of Best Management Practices (BMP) Pollutant Removal Efficiencies

Appendix C

3.0 EXISTING WATER QUALITY DATA FROM MONITORED BMPS

Based on the survey and direct contacts there are two main sources of monitored data in Ontario for BMPs. These are :

- Ottawa-Carleton
- Mississauga

3.1 Mississauga

There are two wet ponds, Lake Wabukayne and Lake Aquitaine, located in Mississauga which have been monitored for an extensive period of time (1977-1986). Although not specifically designed for water quality control, quality data collected on these two lakes provide some insight into quality control by urban lakes.

3.2 Lake Wabukayne

Lake Wabukayne was originally a farmer's pond (Cook's pond) in the valley of Wabukayne Creek. The pond was drained and lined with clay in 1975 in order to construct the lake. The lake was designed as a visual amenity and sediment control device (Hough, undated). The lake was left in a natural state with steep (2:1) side slopes (Figure 3.1 and Figure 3.2). A connection to the municipal water supply was incorporated into the design to supplement low summer flows and offset evaporation.

The original earth dam was replaced with a concrete spillway and dam in 1976. A gabion weir was constructed 1m below the water surface downstream of the main inlet sewers to the lake to act as a sediment barrier. In 1980 the lake was drained to remove sediment and reconstruct the gabion weir so that it extended to just below the water surface. Sedimentation and turbidity problems forced the City to re-route some of the storm sewers which emptied into Lake Wabukayne (Baxter et al., 1985).

3.3 Lake Aquitaine

Lake Aquitaine was constructed on the site of a former farm field in 1977. The lake was designed to provide recreational and visual amenities, as well as flood and pollution control (Figure 3.1 and Figure 3.2). The surrounding area was gently graded (4:1) to drain to the lake.

The lake has an energy dissipator at the inlet, which conveys flow to a concrete sediment basin. The sediment basin has a perforated cement skimming weir which regulates flow to the actual lake. A connection to the municipal water supply was also included for Lake Aquitaine to maintain summer flows. The outlet works for Lake Aquitaine consist of a morning glory spillway with a bottom draw to the Credit River. Land development in the drainage basin of Lake Aquitaine continued throughout the monitoring period. The lake was stocked with 4000 rainbow trout between 1977 and 1979. Other species of fish including pumpkinseed and rockbass appear to be well established in the lake (Gemza, 1989). Algae accumulation along the shoreline was noted within two years of the construction of the lake. Replacement of the pebble shoreline with a sand substrate alleviated this problem.

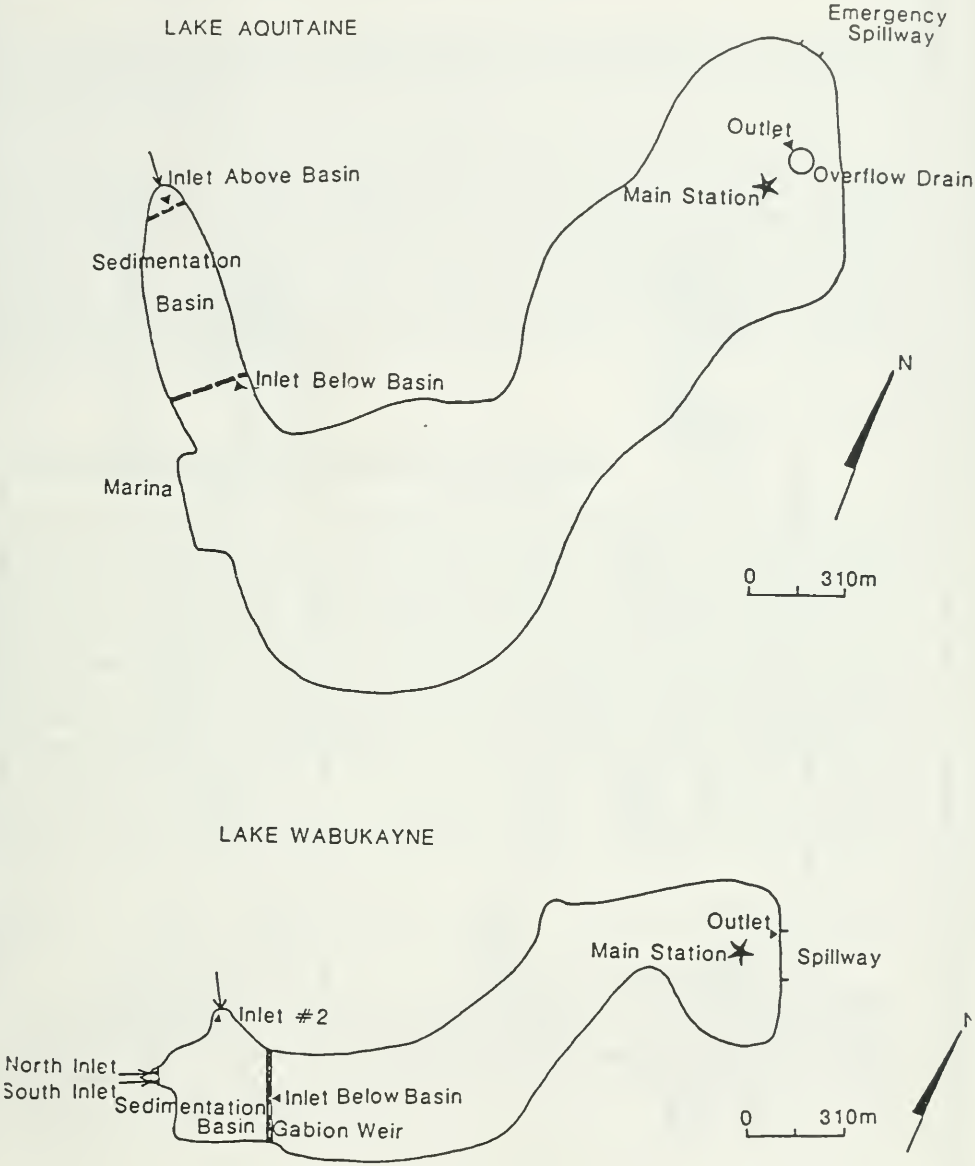
3.4 Monitoring (Lakes Wabukayne and Aquitaine)

The physical characteristics of Lake Wabukayne and Lake Aquitaine are presented in Table 3.1.

Table 3.1. Physical Characteristics of Mississauga Lakes

Characteristic	Wabukayne	Aquitaine
Lake area (ha)	2.0	4.7
Lake volume (cubic metres)	32000	180000
Mean depth (m)	1.6	3.8
Sediment basin area (ha)	0.27	0.38
Lake retention time (days)	13	329
Drainage area (ha)	466	107
Development	residential	residential

Monitored samples were collected weekly (May-September) from 1977-1981, bi-weekly (1983-1984), and monthly in 1982, 1985, and 1986. Grab samples were taken by filling sample bottles directly. No flow quantity monitoring was performed. This provides a potential source of error in the analysis of results. The Lake Wabukayne results are especially prone to error since mean influent concentrations are specified for the three main



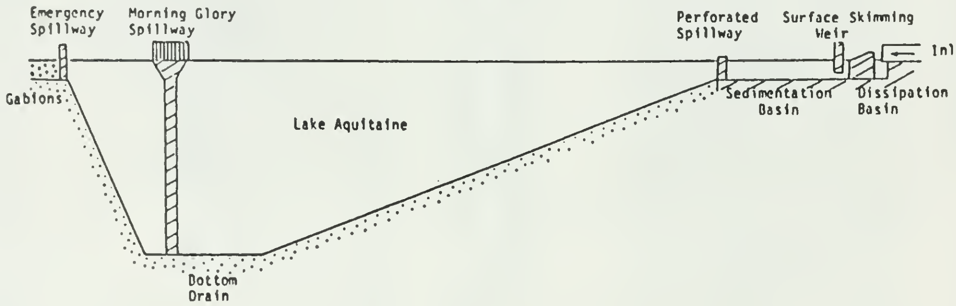
Title

MINISTRY OF THE ENVIRONMENT

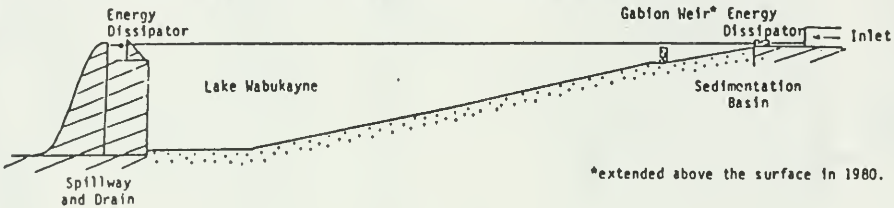
LAKE AQUITAINE AND LAKE WABUKAYNE

Checked	G.B.	Date	JUNE 1990	Job No.	14-90002-101
Drawn	S.M.	Scale	N.T.S.	Figure No.	3.1

Diagrammatic representation of longitudinal section through Lake Aquitaine (not to scale).



Diagrammatic representation of longitudinal section through Lake Wabukayne (not to scale).



*extended above the surface in 1980.

Title

MINISTRY OF THE ENVIRONMENT

PROFILE OF LAKE AQUITAINE AND LAKE WABUKAYNE

Checked G.B.	Date JUNE 1990	Job No. 14-90002-101
Drawn S.M.	Scale N.T.S.	Figure No. 3.2

inlets to the lake. These influent concentrations were averaged (80% of the North and South inlets and 20% of inlet #2, personal comm. with A. Gemza, 1990) since no flow data was monitored at each inlet.

High temperatures (22-26 C) occur in both lakes during the summer months resulting in thermal stratification. Depleted oxygen levels occur in both lakes with Lake Aquitaine becoming anoxic by July. Chloride levels increased through the monitoring period. Chloride levels were highest during the spring period and tended to decrease as the summer progressed. The elevated levels in the spring period are probably attributable to road salting. Levels of nutrients and suspended solids were related to increased runoff during heavy periods of precipitation. Consequently, high nutrient and turbidity levels were frequent during the spring and fall.

3.5 Removal Efficiencies (Lakes Wabukayne and Aquitaine)

Removal efficiencies were calculated for suspended solids, chlorides, total phosphorus, and organic nitrogen (TKN) for both Lake Wabukayne and Lake Aquitaine. These efficiencies are presented in Table 3.2. It should be recognized that the removal efficiencies in Table 3.2 were derived from annual mean influent and effluent concentrations (Gemza et al., 1989), and were not summarized by individual storm. The absence of flow data to determine mass loading, casts further uncertainty on the results shown in Table 3.2. Hence, the results from Table 3.2 are indicators of performance and not actual efficiencies. Influent and effluent were monitored during individual storms for Lake Aquitaine during 1980-1981 by an independent consultant (Hough et al., 1983). Although removal efficiencies were calculated, the retention time in the lake was not accounted for (the influent and effluent were monitored at the same time). The retention time in Lake Aquitaine has been estimated to be 329 days. It would be impractical to try and determine individual storm efficiencies with such a large retention time.

Therefore, the results were not included due to the lack of correlation between influent and effluent.

Table 3.2 indicates that Lake Aquitaine is considerably more efficient than Lake Wabukayne in removing suspended solids, total phosphorus, and total kjendahl nitrogen. The relatively large values of standard deviation indicate the uncertainty of the measurements, the annual variation with meteorological conditions and the variation of performance due to continuing development within the drainage basin.

Table 3.2. Annual Pollutant Removal Efficiencies								
Year	S.S.		Chlorides		T.Phosphorus		T.K.Nitrogen	
	Wab.	Aqu.	Wab.	Aqu.	Wab.	Aqu.	Wab.	Aqu.
1977	89	90	21	<0	45	78	20	50
1978	29	68	17	<0	12	81	4	58
1979	29	85	44	<0	27	79	16	46
1980	90	48	41	<0	64	76	<0	46
1981	78	84	57	<0	49	72	13	59
1982	83	98	55	<0	40	89	<0	66
1983	<0	89	61	<0	8	69	<0	21
1984	<0	95	57	<0	<0	90	21	62
1985	<0	<0	52	<0	<0	65	<0	13
1986	<0	60	57	4	40	75	<0	53
Aver.	<0	65	46	<0	25	77	<0	47
Std.	423	46	15	60	28	8	55	17

It is interesting to note that while Lake Aquitaine is ineffective in removing chlorides, Lake Wabukayne provides some degree of chloride removal. One explanation for Lake Aquitaine's poor performance is its close proximity to industrial and shopping mall complexes. Additional winter salting on these paved areas is thought to produce excess chloride loading on the lake (Gemza et al., 1989).

3.6 Public Perception of Lake Aquitaine and Lake Wabukayne

A study of perceptions and policy implications was conducted on both Lake Aquitaine and Lake Wabukayne (Baxter et al., 1985). Approximately 200 households were interviewed within 10 minutes walking distance from the two lakes.

Approximately 50 % of the people who lived 5 minutes or less from a lake said that the lake was a factor in their decision to live in Mississauga. Most residents (77 %) knew some of their neighbours and reported that the lakes encouraged neighbourliness due to the social and environmental groups organized concerning the lakes. Visual (murky water, algae, scum, garbage, and weeds) and safety problems were the most commonly mentioned problems by residents. Vandalism was also mentioned as a problem, especially at Lake Aquitaine. Seventy percent of the people near Lake Aquitaine felt that the lake should have incorporated more natural areas.

Using the Guttman scale, residents near Lake Aquitaine were estimated to be more satisfied than residents near Lake Wabukayne. Forty nine percent of the respondents felt the city should be responsible for the maintenance of the lakes, while 29 % said the developers should be responsible. Most residents did not see themselves responsible for maintenance, although approximately 30 % were willing to be assessed a fixed fee for maintenance.

3.7 Ottawa-Carleton BMPs

In the mid 1970s, increasing pollution at popular beaches near Hog's Back on the Rideau River, predicated the study of urban storm water pollution and its control (Rideau River Stormwater Management Study). The Regional Municipality of Ottawa-Carleton (R.M.O.C.) undertook a storm water quality monitoring program of all new storm water facilities intended for water quality enhancement. This program reached a peak in the early 1980s and has been declining since 1987.

There were two main reports which affected the design criteria of BMPs in the Ottawa-Carleton area.

The first report was prepared for the Merivale Area in Nepean (Gore & Storrie, 1978). The Merivale Area was analysed using the STORM model and SWM model. The STORM model was used for long term continuous simulation of the Merivale watershed runoff quantity and quality to determine the most efficient volume of storage required for runoff treatment. The SWM model was used to simulate individual events in detail to determine the effectiveness of the recommended storage volume. The study concluded that a storage volume of 9085 m^3 would contain runoff from the majority of storm events.

The second report analysed the monitoring results from the Kennedy-Burnett pond from 1980-1981 (Gietz, 1983). The major recommendation from this report was that water quality facilities in the Ottawa-Nepean area should be designed to provide storage for a 25 mm storm with 72 hours of retention.

The monitoring data and detailed conclusions from the Kennedy -Burnett study are presented in section 3.9.

Information on the following ponds was obtained from the Regional Municipality of Ottawa-Carleton (R.M.O.C.):

East Barrhaven
Kennedy-Burnett Pond
Bridlewood Manor Pond
Hunt Club Ridge Pond
Borden Farm Pond (Fisherglen)

Bentley Pond
Merivale Pond
Colonnade Superpipe
Uplands Pond

The locations of these ponds are shown on Figure 3.3.

Monitored data was available for the first five BMP facilities. Monitored data was available for the outlet of the Colonnade Superpipe and at the inlet to the pipe (outlet of Merrivale Pond). Inflow along the pipe, however, was not monitored. Hence, the actual influent loading was unknown. Comments regarding the efficiency of the superpipe from R.M.O.C. have been summarized.

Most of the monitored data which has been summarized in this appendix is based on influent and effluent concentrations.

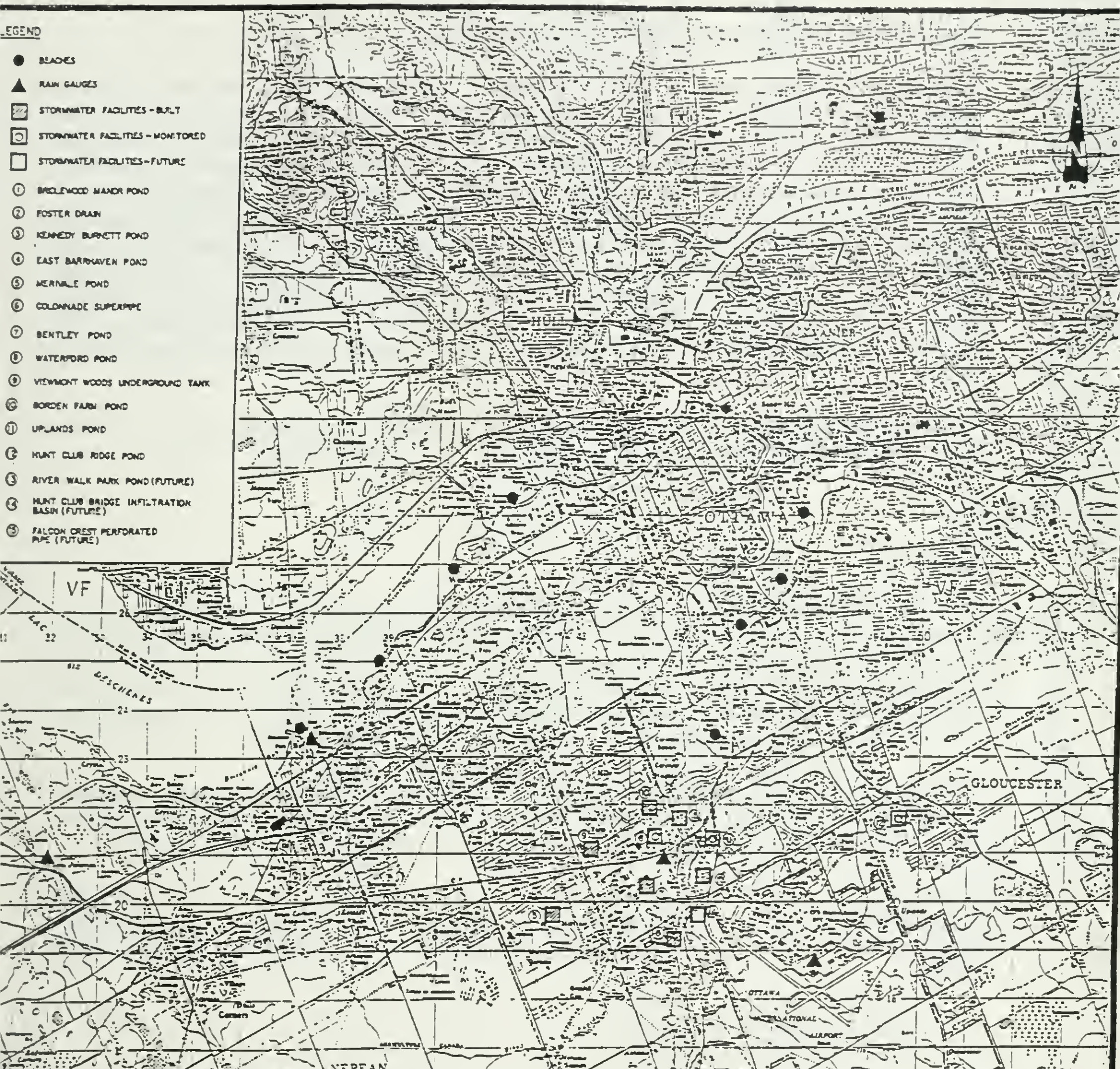
3.8 Barrhaven

There have been two stormwater quality facilities implemented to control the runoff from the Barrhaven storm collector sewer. The sewer which drains approximately 210 ha of residential land and 656 ha of agricultural land discharges into a long shallow ravine.

In 1975 a small dam was built by Delcan, creating a reservoir for treating stormwater runoff. The original outlet was comprised of a 5.5 m spillway and a 20 cm pipe controlled by a valve. This system required three to four days to drain the pond. In October of 1975 the outlet dam was increased by 0.52 m to an elevation of 84.5 m. In March 1976 a large section of the dam washed out. The dam was rebuilt as before, with the addition of a 41 cm relief drain which would drain the pond in 24 hours.

During 1975 and 1976 R.M.O.C. monitored this ravine as a pilot scale study that produced a data report "Stormwater Runoff Treatment by Impoundment - Barrhaven Pilot Study". This data was used for the design and operational criteria for the new full scale facility which was completed by 1982.

The volume for the full scale treatment facility was based on a long term assessment of rainfall events and their resulting runoff volumes ("Report on Stormwater Management for the South Urban Community", Gore and Storrie, 1977). The analysis looked at an 18 year period of runoff events (1515 events). The runoff was based on a runoff coefficient of 0.40. An analysis was made of the 46 worst storms in the 18 year period as well as the entire 1515 events. The number of pond overflows, and relative timing of the overflows (number of hours since the beginning of the storm event) were tabulated for different pond volumes (14160 m^3 - 70800 m^3). The analysis concluded that the 28320 m^3 pond volume was the


LEGEND
BEACHES
RAIN GAUGES
STORMWATER FACILITIES - BUILT
STORMWATER FACILITIES - MONITORED
STORMWATER FACILITIES - FUTURE
1 BRIDLEWOOD MANOR POND
2 FOSTER DRAIN
3 KENNEDY BURNETT POND
4 EAST BARRHAVEN POND
5 MERIVALE POND
6 COLONNADE SUPERPIPE
7 BENTLEY POND
8 WATERFORD POND
9 VIEWMONT WOODS UNDERGROUND TANK
10 BORDEN FARM POND
11 UPLANDS POND
12 HUNT CLUB RIDGE POND
13 RIVER WALK PARK POND (FUTURE)
14 HUNT CLUB BRIDGE INFILTRATION BASIN (FUTURE)
15 FALCON CREST PERFORATED PIPE (FUTURE)
GATINEAU
HULL
OTTAWA
GLOUCESTER
NEPEAN
VF
MINISTRY OF THE ENVIRONMENT
LOCATION MAP OF OTTAWA-CARLETON
BEST MANAGMENT PRACTICES
MARSHALL MACKLIN MONAGHAN LTD
JOB No
SCALE
1 : 50 000
FIG. No
3.3

most efficient based on the entire 1515 events.

Additional work was done by Delcan in 1979 ("East Barrhaven Stormwater Treatment Facility Design Brief"). The number of overflows in July and August, as well as the magnitude of overflows were analysed for the 18 years of rainfall records to determine whether a larger storage volume (42480 m^3) would reduce the magnitude of overflows. Runoff was generated from the rainfall using the SCS triangular unit hydrograph method. The runoff hydrograph was routed through the proposed control structures in the pond to determine the number and magnitude of overflows. Twenty three of the most severe events in the 18 year period were analysed. The report concluded that the increased storage volume had a negligible mitigative effect on the number of overflows and the overflow rates. Hence, the 28320 m^3 storage volume was recommended for the Barrhaven site. The analysis also indicated that half of the rainfall events occurred within four days of each other.

The redesigned Barrhaven pond was completed by 1982. This facility consisted of three ponds with control structures to adjust the water level in each pond.

Monitoring

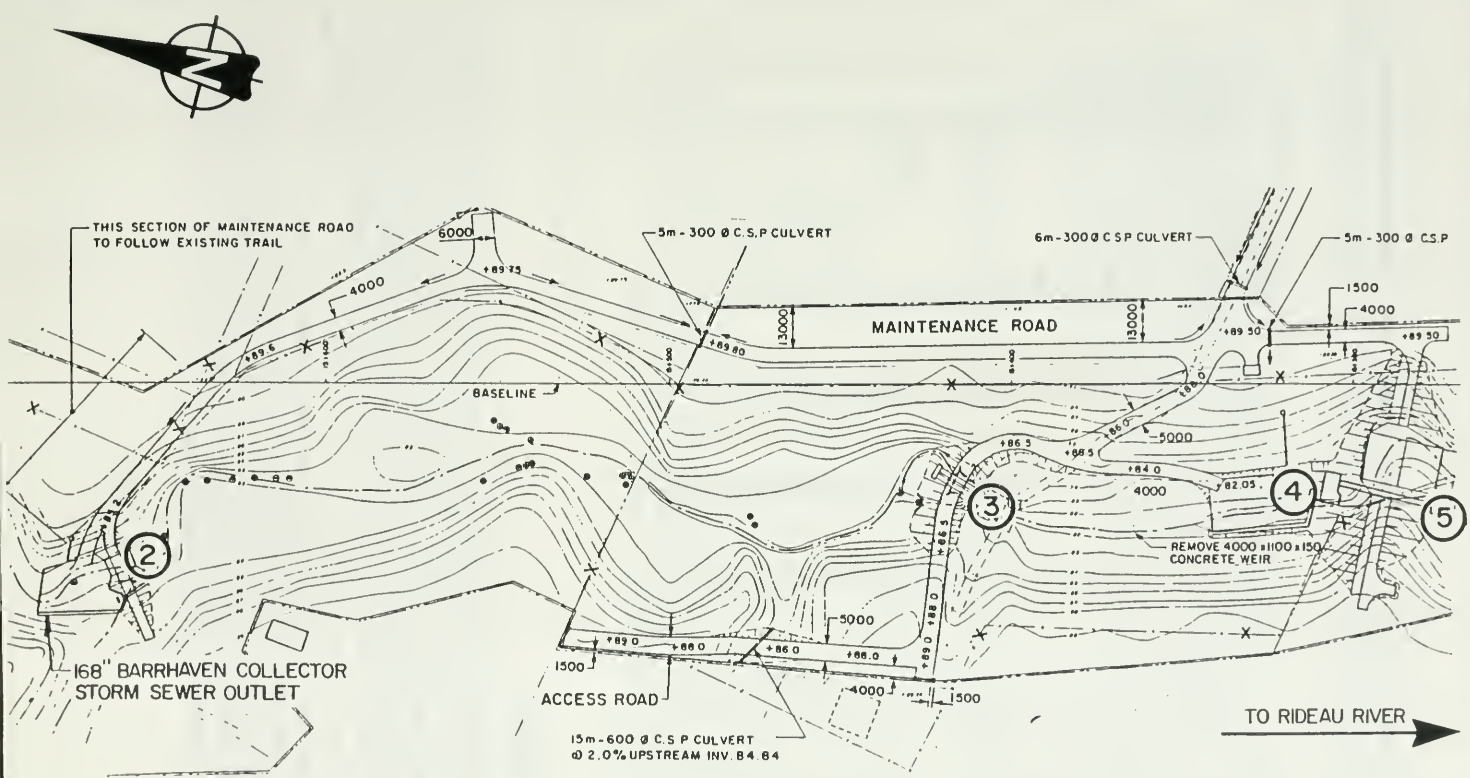
In 1985 and 1986 R.M.O.C. operated and monitored this facility. During the two year monitoring period water quality and quantity data was obtained for a range of rainfall events. The pond was operated in a batch mode with a dry weather volume of approximately 7800 m^3 and a maximum volume of approximately 26400 m^3. Normally the lower crossing influent dry weather flow valve was open to handle the dry weather flows and the dry weather flow valve at the middle road crossing was closed.

In 1985 sampling of the runoff influent, overflow, and treated effluent discharge was done on seven rainfall events. In 1986 only overflow and treated effluent discharge conditions were monitored. Rainfall and effluent level measurements were recorded on site.

Retention times varied throughout the study as a result of consecutive rainfalls and operationally scheduling discharges during working hours. The results showed that after retaining the runoff for an average time of 90 hours, the average discharge concentrations were :

- fecal coliform (310 counts/dl)
- total phosphorus (0.07 mg/l)
- suspended solids (11 mg/l)

Out of the nine monitored events, seven precipitation events with a depth greater than 14.2 mm produced overflows. One of the design criteria for the storage volume of the pond was the frequency of pond overflows which occurred in the first four hours of a rainfall. This criteria was used since the first four hours were considered to be the most important



(2) SAMPLE POINT

Title MINISTRY OF THE ENVIRONMENT			882-1100
BARRHAVEN POND	Checked G.B.	Date MARCH 1991	Job No 14-90002-101
	Drawn B.K.B.	Scale N.T.S.	Figure No 3.4

parameter to reflect the degree of potential pollution on an annual basis (Delcan, 1979). During the monitoring period, only one event produced an overflow within the first four hours of the rainfall storm (24 mm, 06/17/85).

Table 3.3 Removal Efficiencies - Barrhaven						
DATE	RAIN (mm)	TP %	SS %	FC %	Overflow	Retention Time (hr)
1984/07/27	44.69	NA	NA	99	Yes	96
1984/08/06	33.76	NA	NA	NA	Yes	NA
1985/05/27	13.54	60	56	98	No	69
1985/05/31	10.40	85	96	99	No	84
1985/06/06	16.80	68	78	99	Yes	125
1985/06/17	25.92	77	63	98	Yes	81
1985/06/23	18.77	68	86	98	Yes	56
1985/07/15	8.60	39	26	50	No	Contin.
1985/07/16	17.97	74	93	97	Yes	62
1986/06/01	7.10	NA	NA	NA	No	Contin.
1986/06/07	5.30	NA	NA	NA	No	Contin.
1986/06/11	28.04	70	62	85	Yes	88
1986/06/23	30.68	NA	NA	NA	Yes	72
1986/06/27	16.48	NA	NA	NA	Yes	72
1986/07/03	43.73	NA	NA	NA	Yes	72
1986/07/13	9.65	NA	NA	NA	No	72
1986/07/25	29.00	NA	NA	NA	Yes	72
1986/07/29	39.35	NA	NA	NA	Yes	48
Average *	9.17	47	52	56	Yes	75

* Only storms which did not have any overflows were averaged

Operational Problems

In 1985 and 1986 there were two beaver living in the pond. This caused increased maintenance requirements. The debris had to be removed from the culverts at the middle dam at least once a week by R.M.O.C. staff. The beaver activity increased in 1986 to the extent that the mud and sticks effectively raised the level of the second pond which reduced the treatment capacity of the facility, and ultimately produced premature overflows. The removal of the beaver dams resulted in a release of debris into the final (3rd) pond. Occasionally branches were jammed in the automatic electric valve when it closed. The effluent valve would leak until field crews flushed the branch out and closed the valve. By 1987 the beaver had jammed the dry weather pipe at the influent end of first pond causing flow over the low level crossing. This resulted in a higher permanent water level in the first pond which reduced the effective treatment capacity.

Vandalism was also a problem, interfering with both operating controls and monitoring equipment.

Pilot Ultra-Violet Disinfection Facility

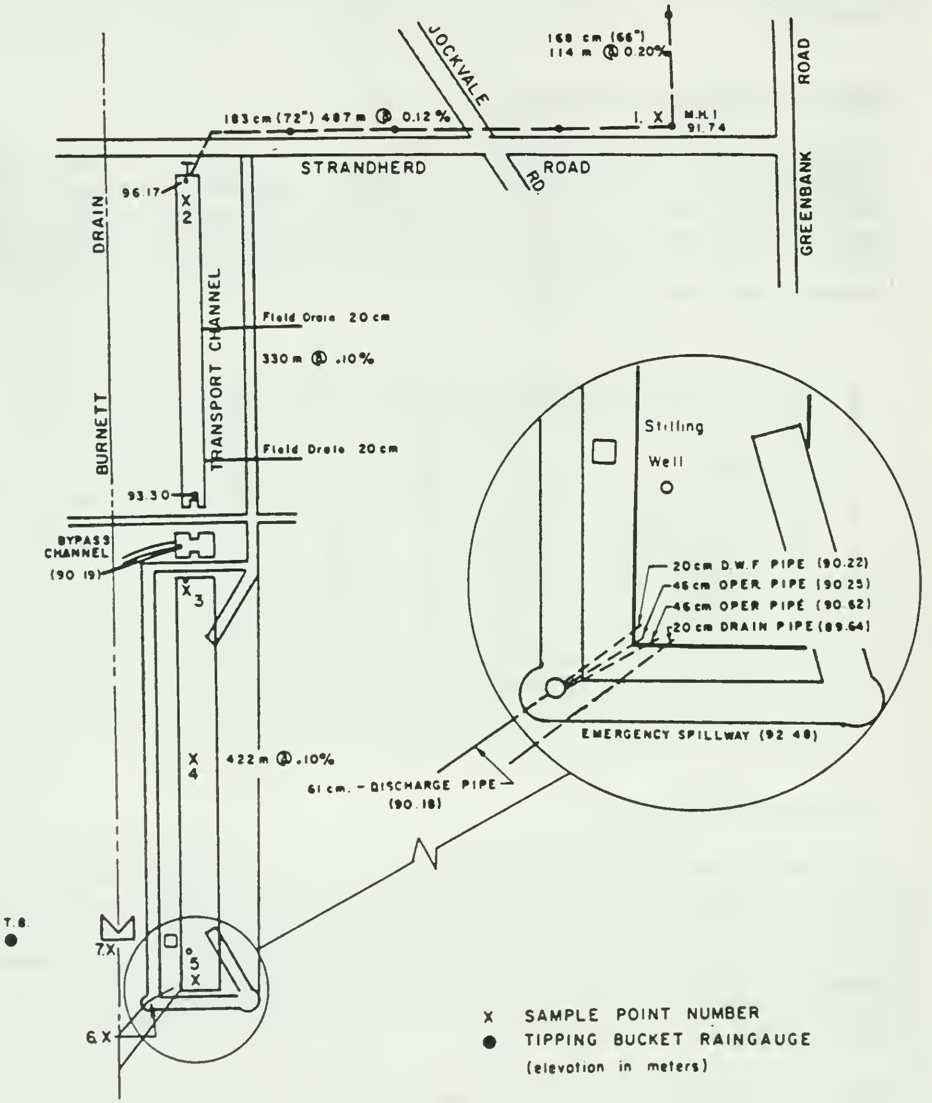
Ultra-violet treatment was tested on a pilot scale in the pond during the months of August to October. The suspended solids concentration and turbidity at the disinfection unit are presented in the table of Ultra-Violet disinfection results. The removal efficiencies should decrease with increased suspended solids loading and increased turbidity at the disinfection facility. The table on ultra-violet disinfection does not reflect this, probably because the suspended solids loading are small.

Ultra-Violet Disinfection Efficiencies -Barrhaven			
Date	FC %	SS (mg/l)	Turb (FTU)
1985/08/25	92.3	5.5	7.5
1985/08/26	94.3	5.2	8
1985/08/27	88.9	4.35	11
1985/08/28	98.3	8.43	13.2
1985/10/01	93.1	15.3	13.6
1985/10/02	96.9	19.3	12.2
Average	94.0	9.68	10.9

3.9 Kennedy-Burnett Pond

The Kennedy-Burnett Pond was built in November 1978. It is located in the City of Nepean, and drains into the Jock River. The pond was designed to store runoff from a 2 year storm (35 mm) with a 2 hour duration. The storage volume in the pond (25000 m^3) was sized to accommodate a total of 160 ha. The detention pond cross-section was trapezoidal with a bottom width of 18 m, top width of 30.5 m. The pond was rectangular in shape with a length of 422 m (Figure 3.5). The pond was designed to maintain a permanent pool of 2000 m^3.

During dry weather operation a dry weather flow pipe was used to maintain a constant water level in the pond. In the event of a storm, a float-operated valve would seal the outlet once the water level rose over a pre-determined level. Runoff was stored until the discharge valves were opened manually (usually 24-96 hours of settling).



Title MINISTRY OF THE ENVIRONMENT KENNEDY-BURNETT POND	Checked G.B.	Date JUNE 1990	Job No. 14-90002-1
	Drawn S.M.	Scale N.T.S.	Figure No. 3.5

Development of the 160 ha drainage area occurred throughout the monitoring period at the Kennedy-Burnett facility. In 1983, the pond served a catchment area of 60.7 ha. The total contributing area ranged from 33 to 45 ha. During construction, the non-contributing area increased. (Gietz, 1983) [Note: Contributing area was defined as area which drained to the storm sewer network which outlets to the Kennedy-Burnett Pond. The non-contributing area increased during construction due to roads being built-up compared to the surrounding development prior to completion.]

For most of the study period, the percentage of area which was impervious ranged from 31-33%. From June 1980 to August 1981, the area under construction ranged from 1.4 to 4.1% of the contributing catchment.

The Kennedy-Burnett Pond was operated in batch mode in 1980 and mostly in continuous flow mode in 1981.

3.9.1 Summary of Batch Operation

Some parameters were associated with dry weather flows, and negative removals were observed for these parameters when dry weather flow loadings were not included in the total load. Runoff loading reductions were calculated by applying a mass balance on loadings. Influent concentrations included both the runoff concentration as it entered the pond and the pond concentration prior to the runoff entering. Effluent values were calculated based on the discharge volume and the discharge concentration. Table 3.4 presents the batch operation results with available data.

Table 3.4 Removal Efficiencies - Kennedy-Burnett (Batch)

Date	Runoff (m^3)	TP %	SS %	FC %	FS %	TON %	BOD %	Zn %	Pb %	Reten. (hr)
1980/07/08	1200	92	97	99	98	63	76	49	65	75
1980/07/15	1500	35	99	99	99	83	50	45	60	52
1980/07/28	2900	85	99	97	99	22	14	25	36	45
1980/08/27	1000	95	98	99	99	80	63	19	67	49
1980/09/02	1300	86	95	99	99	20	-24	-33	-31	73
1981/08/05	15000*	89	97	94	63	31	43	—	—	60
Average *	1580	79	98	99	99	54	36	21	39	59

* Pond Overflow (not included in average)

3.9.2 Results of Batch Operation

The Kennedy-Burnett Pond was very effective in removing suspended solids. BOD removal was less effective (at times the BOD effluent concentrations equalled the M.O.E. criteria of 6 mg/l).

The pond was unsuccessful at meeting the M.O.E. body-contact criteria for fecal coliform (FC) and fecal streptococcus (FS) (FC = 100 C/100 ml and FS = 20 C/100 ml). Only 2 batches met the FC criteria while none met the FS criteria. The criteria failure is due to high coliform loading rates during storm periods since the removal efficiencies were near perfect.

This emphasizes the need to evaluate downstream water uses in the selection of water quality facilities. Even the most efficient wet pond may not provide enough protection to satisfy water contact recreation.

As in other studies (Qureshi, 1979), the Kennedy-Burnett study determined that bacterial reduction, while related to the retention time, was greatly affected by mixing, dilution, and other factors (wind effects) in the pond (Gietz, 1983).

3.9.3 Summary of Continuous Flow Operation

In the continuous flow operation mode, the pond contained a dry weather flow storage of approximately 6700 m^3. The pollutant concentrations were averaged since the water quality was uniform across the pond (due to the pond not usually containing polluted runoff). Geometric means of bacterial densities were used. Sampling was performed for 11 events from the end of May to October, except for August, 1981. Table 3.5 presents the results based on mass loading for the continuous mode of operation. Not all of the events produced information which was useful in assessing pond performance due to field conditions, power losses, and instrument failure.

Table 3.5 Removal Efficiencies - Kennedy-Burnett (Cont.)							
Date	Runoff (m3)	TP %	SS %	FC %	FS %	TON %	BOD %
1981/05/26	120	93	95	99	100	85	82
1981/05/27	3600	83	92	97	98	43	34
1981/05/30	530	80	92	100	100	61	80
1981/06/06	348	97	99	100	100	88	64
1981/06/15	11036	66	77	42	43	49	-9
1981/06/16	3029	83	89	86	80	40	67
1981/06/30	480	91	100	92	99	33	89
1981/10/06	1074	94	98	64	—	—	48
Average *	2527	86	93	85	86	57	57

3.9.4 Analysis of Pond Performance

The primary mechanisms for pollutant removal in the continuous mode were decay and settling rather than dilution and mixing (Gietz, 1983). The degree of pond mixing was more complete in the batch mode, with the pond contents being completely mixed in 2-3 days.

The continuous operation did not provide as much bacteriological control as the batch operation, but produced slightly better reductions of BOD.

The continuous mode of operation was found to produce polluted effluent for a longer period of time than the batch mode of operation.

The batch mode was determined to be the more effective type of operation for pollutant removal over the long term (Gietz, 1983). Based on the monitoring results the Regional Municipality of Ottawa-Carleton recommended that ponds draining to the Rideau River, such as the Kennedy-Burnett (or Barrhaven), should be designed to operate in the batch mode, with a minimum retention time of three days (72 hrs). It was also recommended that the ponds be able to discharge their contents within 24 hrs. A minimum of 2 overflows per year was recommended in the design of pond storage volume.

3.9.5 Hydraulic Pond Overflows

Several observations were made from the monitored data from the period 1980-1981 by R.M.O.C.. A relationship was developed which related rainfall in the Kennedy-Burnett drainage area to runoff influent to the pond. This relationship was used in conjunction with a 10 year rainfall record to determine the number of overflows which could be expected for different storage volumes in the pond.

The storage volume for 2 overflows per summer was calculated to be 7300 m^3. The number of overflows would increase to 5 if a storage volume of only 4500 m^3 was provided. These storage volumes include 3 days (1000 m^3) of dry weather storage (3 days of retention were recommended for fecal coliform removal). The required storage volume (7300 m^3) to limit the number of overflows per summer to 2 is much less than the volume provided (25000 m^3) in the Kennedy-Burnett pond. This is expected since the rainfall-runoff relationship was based on the level of development in the watershed in 1981 (45 ha) whereas the pond volume was based on the ultimate drainage area (160 ha).

3.9.6 Pond Sediment Accumulation

The pond was cleaned out in the late spring and the fall to measure the spring and summer sediment load. Spring runoff produced approximately 30-50 tonnes of sediment whereas the summer load ranged from 10-40 tonnes. The summer load was more dependent on amount of rainfall than amount of development (construction) in the watershed (Gietz, 1983).

The pond was designed with a cement bottom for ease of sediment removal. The pond was initially drained by placing stop logs at the inlet to the facility. The bottom of the pond was then scraped to remove the sediment. Problems occurred due to stop log leakage which converted the sediment into mud. The leakage problems were overcome by sandbagging the inflow culvert and pumping any seepage into the bypass channel. Once the inlet to the pond was sealed the pond bottom drain was opened, and the sediment was allowed to drain.

The sediment was still too wet to haul after several days of draining. A drainage channel was created along the centre of the pond bottom to assist in drainage. After draining the sediment was removed by front-end loaders and transported to a sanitary landfill by dump trucks. The time required for sediment removal was 3 days to several weeks depending on dry weather flow and rainfall.

The observed rate of annual sediment deposition was 4 cm at the inlet and 15 cm at the outlet.

Algae accumulation was prevalent during the summer months in the Kennedy-Burnett Pond. A 2 m wide band (dense mat the complete depth of the water) of mostly non-mobile green fibrous algae was observed along both edges of the pond - summer. Persistent algae growth was also observed at both the inlet and outlet ends of the pond. By the end of July, there was sufficient growth to make the pond aesthetically unattractive. The algae remained until the fall cleanout. The algae buildup was not considered a problem in the Kennedy-Burnett pond due to its rural setting.

3.9.7 Maintenance Costs for Kennedy-Burnett Pond

The following maintenance expenses were incurred during the first five years of operation:

- inlet culvert pipe cracked due to seepage and
  settling - excavated and repaired $2000-$3000
- grass cutting and sediment removal - 1982 - $3000
  1981 - $2700
  1979 - $2000

These costs represent an annual maintenance expenditure of less than 1% of the capital cost.

3.9.8 Design Guideline Implications

The Regional Municipality of Ottawa-Carleton used the results of the Kennedy-Burnett monitoring (Gietz, 1983) to recommend general design guidelines for water quality ponds.

General Design Criteria:

1. Determine the parameters of interest and the quality limits that the treated runoff will have to meet.

2. Study the treatability of runoff from the area of interest to determine detention times, removal or decay rates for parameters of interest.

3. The runoff collection system should be designed to provide the maximum time for runoff to infiltrate pervious surfaces. Where applicable, temporary swale and parking lot storage should be used to reduce maximum runoff flow rates and provide some mixing and dilution of pollutants.

4. The pond design should consider the number of overflows annually, and the effluent concentration for the parameters of interest. Percent removals may be useful on a long term basis.

5. The pond overflow should be sited near the runoff inlet such that overflows would largely bypass the main pond storage volume. Further evaluation of mixing may suggest better overflow locations. The treated effluent outlet can also be put in the same structure as the overflow, but other locations may be just as suitable.

6. Pond operation mode should be selected after considering the capability of the receiving water to assimilate treated effluent load.

7. Access to pond bottoms should be provided for cleanout of sediment.

8. The impact of sequential or simultaneous discharge of several ponds on the receiving water must be considered.

3.9.9 Baffles

In 1984, baffles were introduced into the pond to spread the flow evenly across the width of the pond. The flow was spread across the pond to prevent dead zones in the pond and to assist in mixing of pond contents. Accordingly, the baffles were placed near the influent to the pond. The baffles were constructed by placing blocks across the pond leaving 150 mm spaces between each block. The blocks were stacked 3 high.

Three events were monitored in 1984 with the baffles in place. The pond was operated in the continuous mode with the baffles installed. Table 3.6 presents the removal efficiencies of the pond based on mass loading with the baffles in place. The limited monitoring data indicate that the addition of the baffles did not increase the removal efficiencies for total phosphorous, suspended solids, or fecal coliform.

Table 3.6. Kennedy-Burnett Efficiencies - Baffles

Storm	Rainfall (mm)	TP %	SS %	FC %
July 10-11, 1984	12.3	60	80	79
July 27, 1984	29.2	85	98	98
August 22, 1984	27.6	48	81	78
Average	23.0	64	86	85

3.9.10 Modifications to the Kennedy-Burnett Pond

Modifications were made to the Kennedy-Burnett pond (Cumming-Cockburn, 1985) because there was insufficient grade to drain a proposed sub-division (Barrhaven N5) without risking basement flooding. The following modifications were implemented :

- transport channel deepened by 0.45 m for a 0.1% slope from the pond outlet to the sewer
- transport channel widened to 25.5 m (from 2.4 m) with 3:1 slopes
- emergency spillway elevation lowered to 91.3 m to reduce the surcharge by 0.55 m

- bypass channel and access crossing removed where the transport channel drained into the storage pond and replaced by box culverts under the farm access road
- new outfall constructed into the transport channel from the Barrhaven N5 sub-division

3.10 Bridlewood Manor Pond

The Bridlewood Manor Pond is located in the Township of Nepean and outfalls to the Monahan Creek (Figure 3.6). The pond was designed in 1975. Several studies were researched in an attempt to develop the best design. The overall result is an assimilation of the individual design reports. Based on a 25 mm storm with a summer runoff of 20% of the rainfall, the 5660 m^3 pond could handle a tributary area of 111 ha.

Approximately 27% of the basin was covered by impervious areas. It was assumed the pond would remove 60% of the suspended solids based on a University of Windsor study. The 0.40 ha (100 m x 95 m x 75 m) pond is triangular in shape with 3:1 side slopes. The average depth in the pond is approximately 1.5 m. The outlet structure contains an orifice plate to throttle low flows, and a sluice gate, and stop logs to control the operating level in the pond.

The initial objective was to provide quality improvement by settling, with the pond being designed to allow manual or automatic emptying of the pond. The automatic emptying of the pond would be accomplished by the orifice plate with a weir, the sluice gate, and the stop logs. Up to the weir the pond would discharge through the orifice. Once the pond level rose to the weir elevation, the discharge would be the combination of weir and orifice flow. A combination of orifice flow, weir flow, and flow through the sluice gate would occur if the pond rose to the level of the sluice gate (subject to the number of stop logs installed).

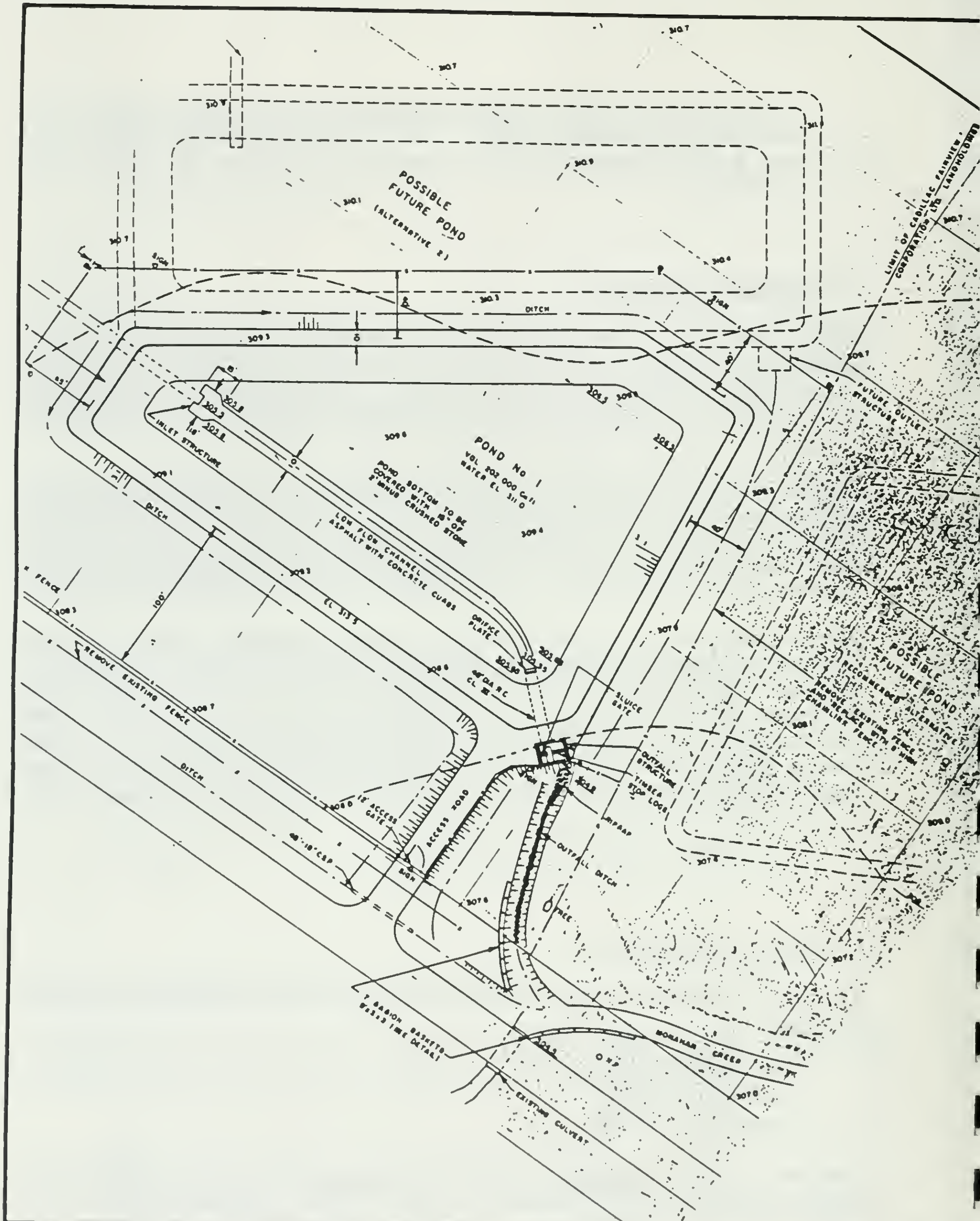
No monitored data for this pond was provided.

3.11 Hunt Club Ridge Pond

The Hunt Club Ridge Pond receives runoff from 62 ha of land with a variety of land uses :

- residential (32 ha)
- institutional (8 ha)
- greenbelt (22 ha)

The pond, which was designed in 1977 (Design Report, January 1978), discharges into Sawmill Creek. The storage volume for this pond (1940 m^3) was based on the Merivale



Title

MINISTRY OF THE ENVIRONMENT

BRIDLEWOOD MANOR POND

Checked	G.B.	Date	JUNE 1990	Job No.	14-90002-101
Drawn	S.M.	Scale	N.T.S.	Figure No.	3.6

Industrial Park storage volume using a ratio of the relative drainage areas (area x runoff coefficient). The pond is 105 m long by 35 m wide and is kidney-shaped (Figure 3.7). The normal depth in the pond is 1.5 m.

Under normal operation, the facility provides 2265 m^3 of storage. An adjustable sluice gate is used to control the discharge from the pond. Stop logs are used to control the depth in the pond. The pond is operated during the summer months (June to September) when the downstream beaches are expected to be open. The pond can be completely drained by removing all the stop logs manually.

Only one storm event was monitored at this site, August 23- 24, 1979. The following TP and SS removal efficiencies were calculated (FC data not available) :

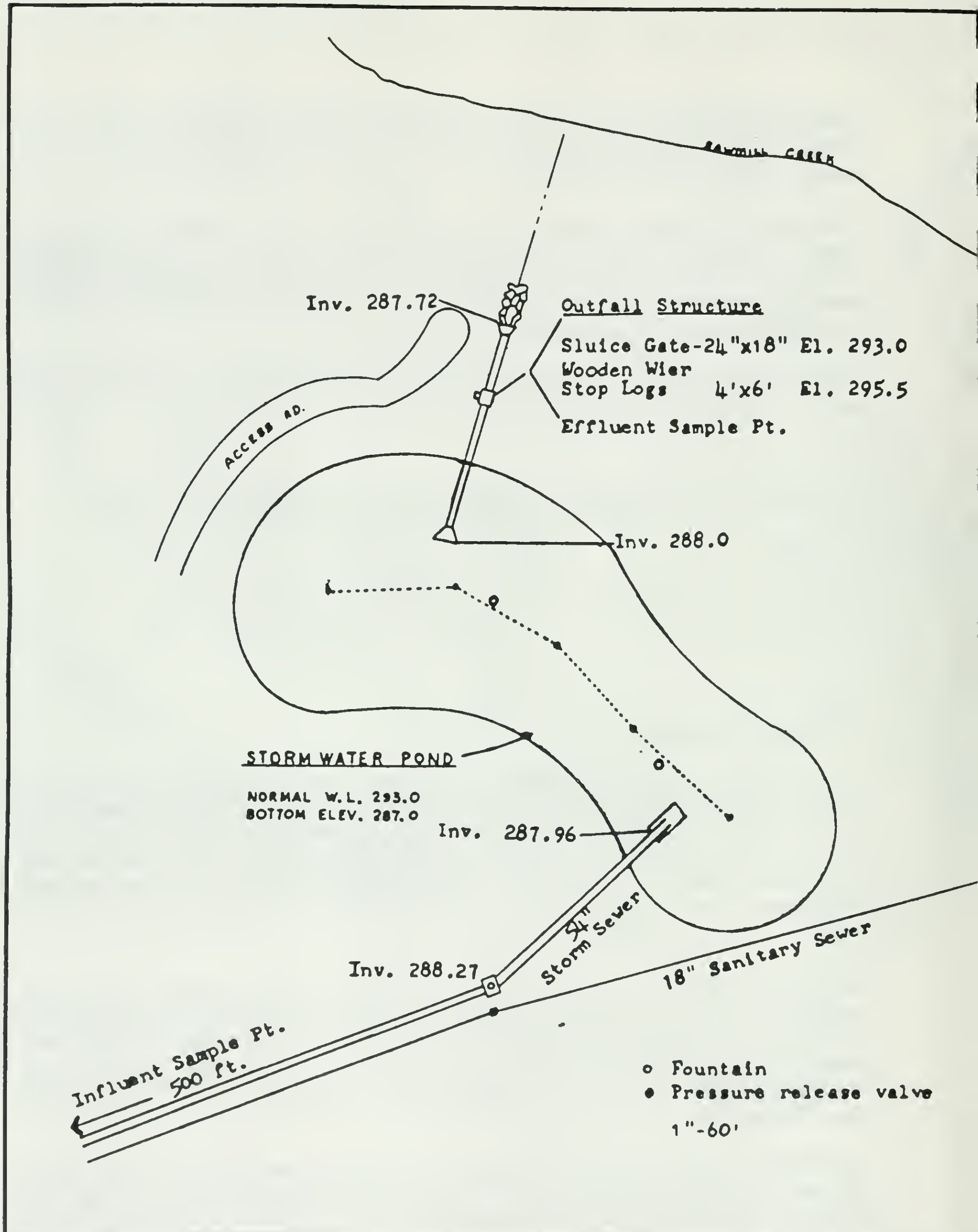
Table 3.7. Removal Efficiency - Hunt Club Ridge			
Storm	Rainfall (mm)	TP %	SS %
August 23-24	24.4	62.5%	89.6%

3.12 Borden Farm Pond

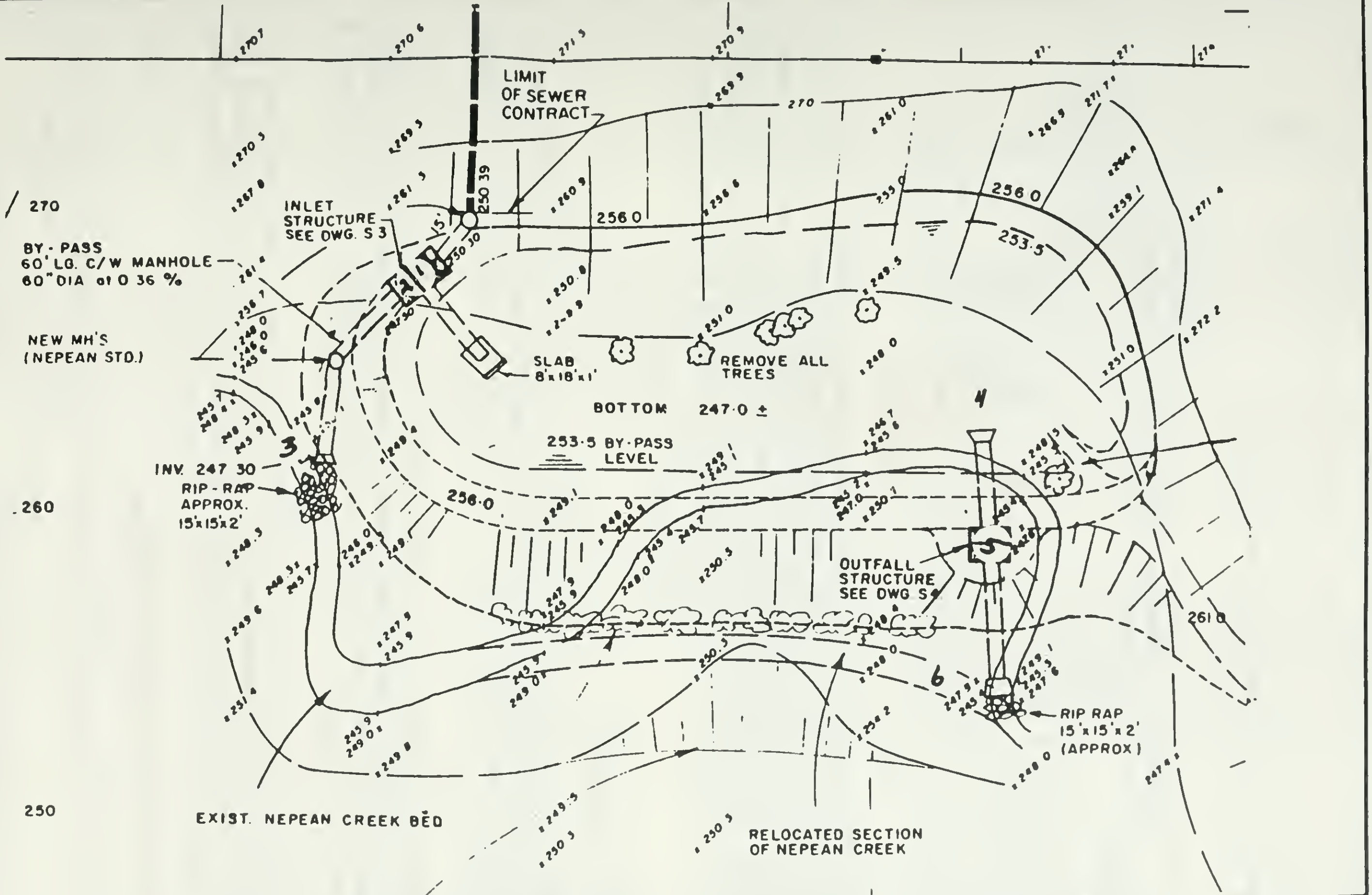
The storage for the Borden Farm Pond was based on the Merivale Report (Gorre and Storrie, 1978). This report specified the storage volume required to detain runoff from a 25 mm rainfall for 72 hours. The required storage from this study was factored on the CA ratio (Rational Method runoff coefficient) of the pond drainage area to the Merivale study area. The required Borden Farm pond storage volume based on the 86 ha of residential development drainage area was calculated to be 2265 m^3. The actual Borden Farm pond layout accommodated 2690 m^3.

The pond is situated in the natural Nepean Creek valley. The north and east side of the pond are formed by the natural Nepean Creek valley. Man made dykes (elevation 78m) dictate the south and west side boundaries of the pond. The maximum design water elevation in the pond is 77.3 m. The average depth of the pond is 2.1 m. The surface area of the pond is 1281 m^2. The approximate dimensions of the pond are 60 m long by 20 m wide (Figure 3.8).

The effluent sluice gates were closed at the beginning of a rainfall, then manually opened after the runoff had been detained for 72 hours. The monitored data for 1986 and 1987 indicated that the pond was actually operated with only 48 hours of retention (the gate



Title			
MINISTRY OF THE ENVIRONMENT HUNT CLUB RIDGE			
Checked G.B.	Date JUNE 1990	Job No. 14-90002-10	
Drawn S.M.	Scale N.T.S.	Figure No. 3.7	



Title: MINISTRY OF THE ENVIRONMENT — BORDEN FARM			
Checked: G.B.	Date: JUNE 1990	Job No. 14-90002-101	
Drawn: S.M.	Scale: N.T.S.	Figure No. 3.8	

openings were scheduled during working hours).

Table 3.8. Removal Efficiencies - Borden Farm						
Date	Rain (mm)	TP %	SS %	FC %	Overflow	Retention Time (hr)
1987/06/26	47.60	30	67	97	No	48
1987/07/02	12.47	63	52	15	No	48
1987/07/24	43.97	50	58	94	Yes	48
Average	34.68	46	59	66	No	48

There was a problem with the operation of the stop logs at the outlet of this pond in 1987. The stoplogs were not water-tight, and as a result, frequently leaked. This problem resulted from the rough concrete in the influent and effluent chambers not providing a good sealing surface for the stoplogs. Leaking also occurred between the stop logs. As such, very little runoff was actually retained for 72 hours. Thus the removal efficiencies in Table 3.8 must be viewed with caution since they do not reflect the intended operation of the pond.

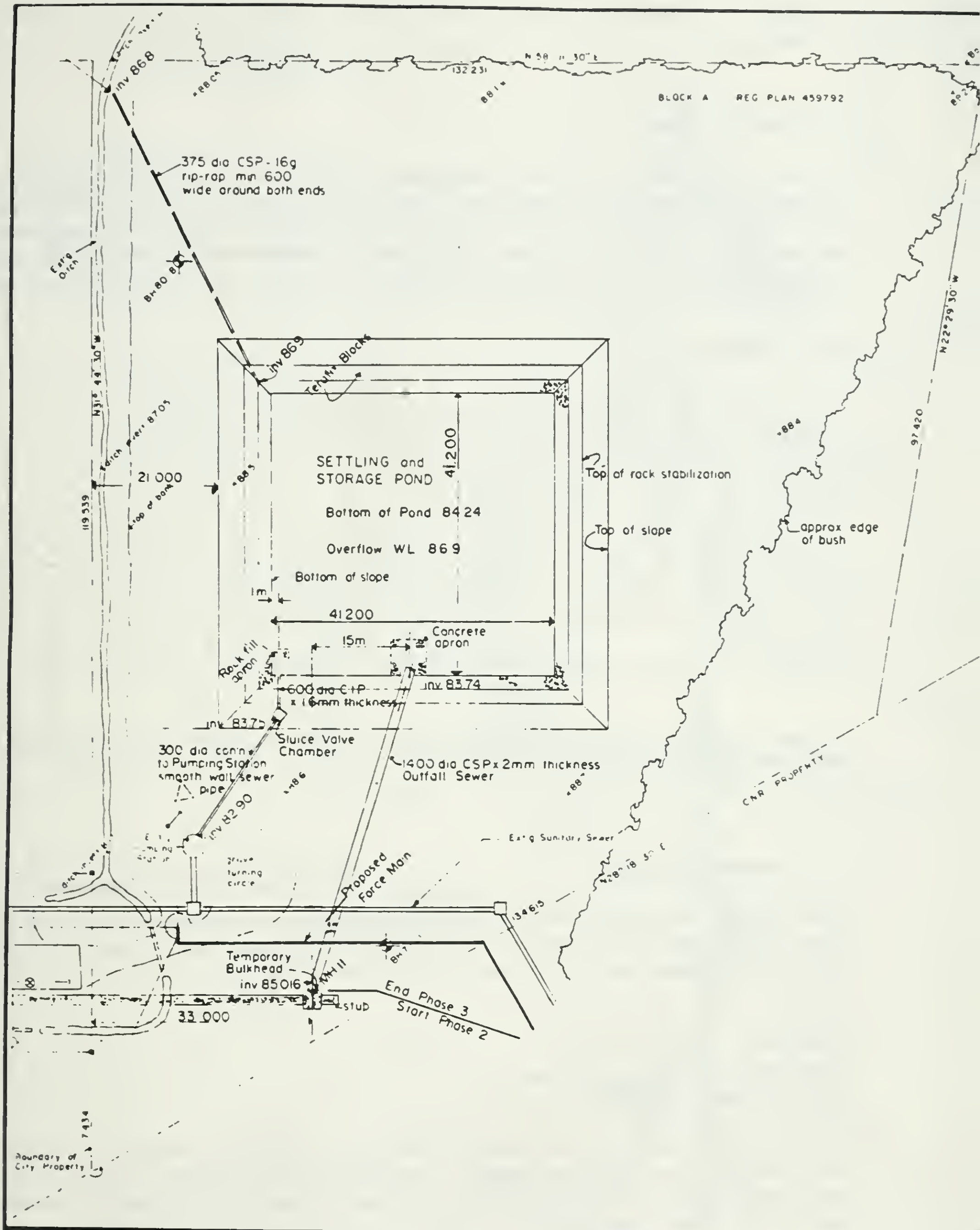
3.13 Bentley Pond

The Bentley Pond in the City of Nepean is located at the easterly end of Bentley Avenue. The pond was constructed in 1980 along with the storm sewer on Bentley Avenue as a retrofit for water quality purposes. The drainage area comprises 21 ha of industrial development.

The pond has a storage volume of 4100 m^3 and is square in shape (41 m x 41m) (Figure 3.9). The storage volume was based on the retention of a modified 5 year storm (average intensity for a 5 year storm occurring in 80 minutes multiplied by a storm duration of 2 hours). The maximum water depth in the pond is 2.66 m.

The pond operates in a batch mode and automatically empties into a storm sewer by a pump at a uniform discharge rate of 0.07 cms after a retention period of 48 hours. The time required to drawdown the design storage volume was 16 hours. The retention time of 48 hours was based on a 90 % removal of the influent bacteria.

No monitoring was performed on this pond.



Title

MINISTRY OF THE ENVIRONMENT

BENTLEY POND

Checked G.B.	Date JUNE 1990	Job No. 14-90002-101
Drawn S.M.	Scale N.T.S.	Figure No. 3.9

3.14 Merivale Pond

The Merivale Pond serves 183 ha of residential (25 ha) and open space (NCC Greenbelt 158 ha) land. The pond was constructed in 1982 and drains into the Colonnade Superpipe which eventually drains directly into the Rideau River (Figure 3.10). In 1985, and during the month of August, 1986, the pond was operated in a batch mode. Throughout the rest of 1986, the pond was operated in a continuous flow through mode. No overflows of the Merivale Pond were recorded.

Efficiencies were calculated for one storm in 1984 and three storms in 1985 .

Table 3.9. Pollutant Removal Efficiency - Merivale

Storm	Rainfall (mm)	TP %	SS %	FC %
Aug 23-24, 1984	30.7	41.1	71.7	65.5
Jun 1-4, 1985	13.9	17.7	64.0	84.0
Jun 17-21, 1985	25.4	80.6	96.5	98.6
Jul 29-Aug 2, 1985	25.2	44.0	99.5	98.8
Average	23.8	45.9	82.9	86.7

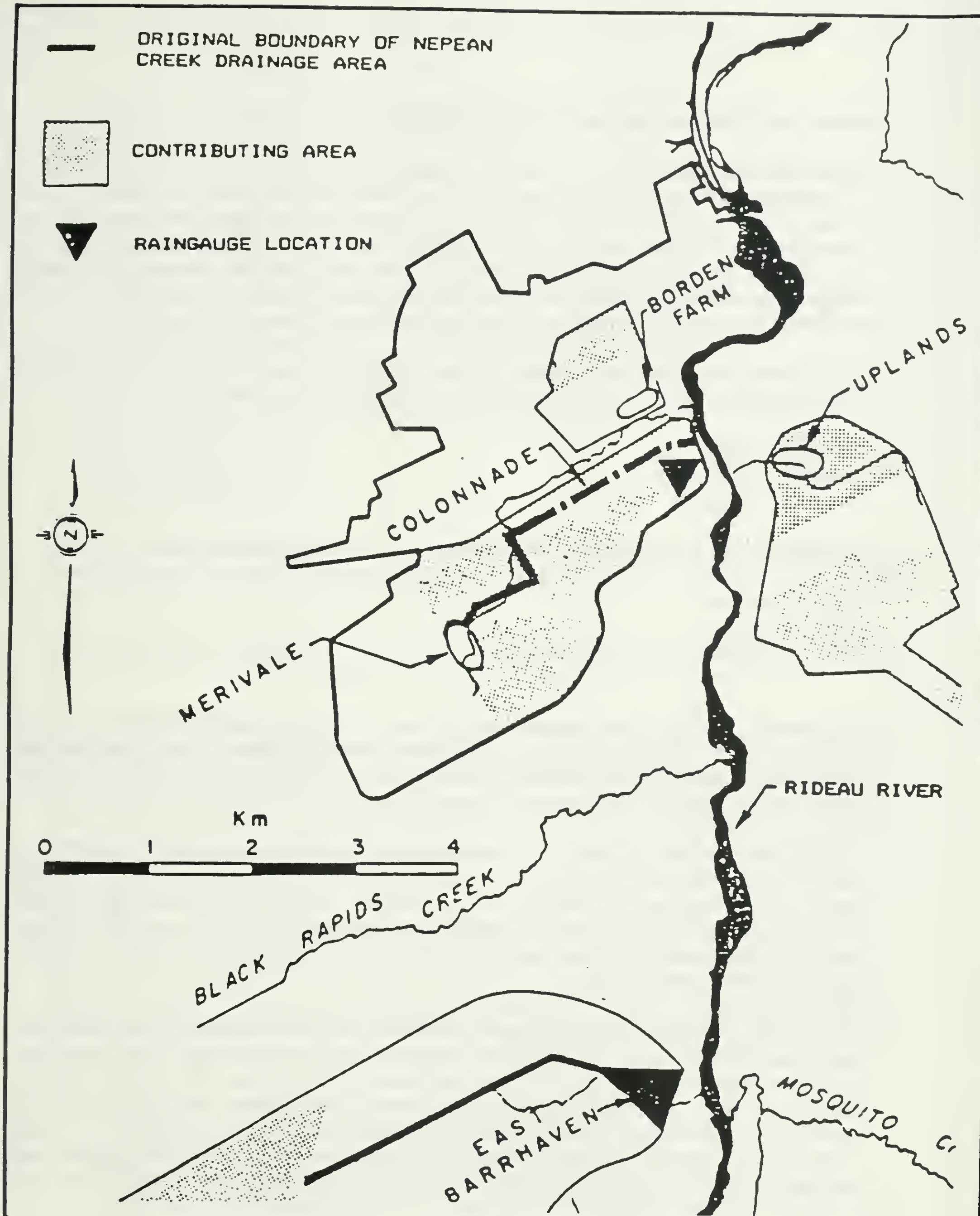
Average values for influent and effluent concentrations were used to assess the removal efficiencies during the monitored period.

3.15 Colonnade Superpipe

The Colonnade Superpipe is the original storm trunk sewer constructed in 1975. This 3 m diameter pipe spans 2682 m from the Merivale Pond to the Rideau River (Figure 3.10). The pipe serves a drainage area of 526 ha with the following land uses :

Industrial: 285 ha (54 %)
Residential: 30 ha (6 %)
Open Space: 28 ha (5 %)
Merivale Pond: 183 ha (35 %)

The discharge from the pipe is controlled by sluice gates, while the volume of storage is controlled by weir settings. The storage volume in the pipe varies from 3200 m^3 at the lowest weir setting to 7300 m^3 at the highest weir setting. As the watershed became developed it was necessary to keep the weir setting at its lowest value to increase the pipe



Title: MINISTRY OF THE ENVIRONMENT LOCATION OF MERIVALE POND AND COLONNADE SUPERPIPE	882-1100		
	Checked G.J.B.	Date JULY 1990	Job No. 14-90002-I01
	Drawn K.J.G.	Scale AS SHOWN	Figure No. 3.10

capacity and mitigate upstream flooding problems.

Insufficient monitoring data is available to estimate the efficiency of the superpipe itself. The effluent for the Merivale Pond was documented as one source of influent to the Colonnade Superpipe, but the remainder of the influent occurs at different points along the superpipe itself. There was no monitoring of the influent from the remaining 343 ha. It was decided that the analysis of the efficiency of the superpipe was not worth the hazards of sampling the influent since the pipe is a large and deep system which services a large industrial area. As such the pipe system frequently contains various gases.

The effluent out of the control structure from the pipe was monitored from 1984 to 1987. Three overflows were recorded during the period from 1984 to 1986 :

June 17th, 1985
Aug 9th, 1986
Aug 21st, 1986

Twenty five storms were monitored for water quality during this same period:

1984 - 10 events
1985 - 6 events
1986 - 9 events

In 1984 and 1985, the pipe was operated with the manually- operated sluice gate opened 300 mm. Data from the monitored events showed discharges through the open valve had fecal coliform levels ranging from 6600 to 79000 counts/dl. Scouring of the bottom was also noted as a problem during this mode of operation.

In 1986, the pipe was operated in a continuous mode with the weir settings at their lowest (3200 m^3) and with the sluice gates closed, except for the month of August when the pipe operated in a batch mode. Both of the two overflow events in August had high coliform levels (Aug 09 (21mm) - 20000 counts/dl, Aug 21(20mm) - 27000 counts/dl). Bottom sediments were resuspended and washed out during the discharge of these events, especially when the water level was low.

The monitored effluent from this pipe indicated that it was considerably undersized for water quality enhancement. The rainfall runoff records indicated that 3200 m^3 of runoff could be expected from the 343 ha drainage area during a 6 mm rain storm (based on subtracting Merivale effluent from Colonnade flow). The required volume of storage to contain the recommended 25 mm rainfall for 72 hours (R.M.O.C., 1983) (runoff + 3 days of dry weather flow) would be 22100 m^3 (3 x 2800 m^3 + 13700 m^3). The available pipe storage (3200 m^3) is too small to mitigate water quality degradation from storms of this size.

As such, the monitored data indicated that the pipe was ineffective in mitigating pollutant migration.

3.16 Uplands Pond

The Uplands pond is an online pond which accepts flow from the Hunt Club Creek (Ditch) when discharge in the creek is greater than 15 l/s. The drainage area at the creek by the pond is 348 hectares. The land use in this drainage area is comprised of

- 126 ha CFB and Airport
- 93 ha residential
- 40 ha woodland
- 73 ha golf course
- 16 ha open space

A dam in Hunt Club Creek diverts flow from the creek to the pond. A hydro-brake is used in the diversion chamber to permit low flows to bypass the dam and maintain normal creek flows when the flow rate is less than 15 l/s.

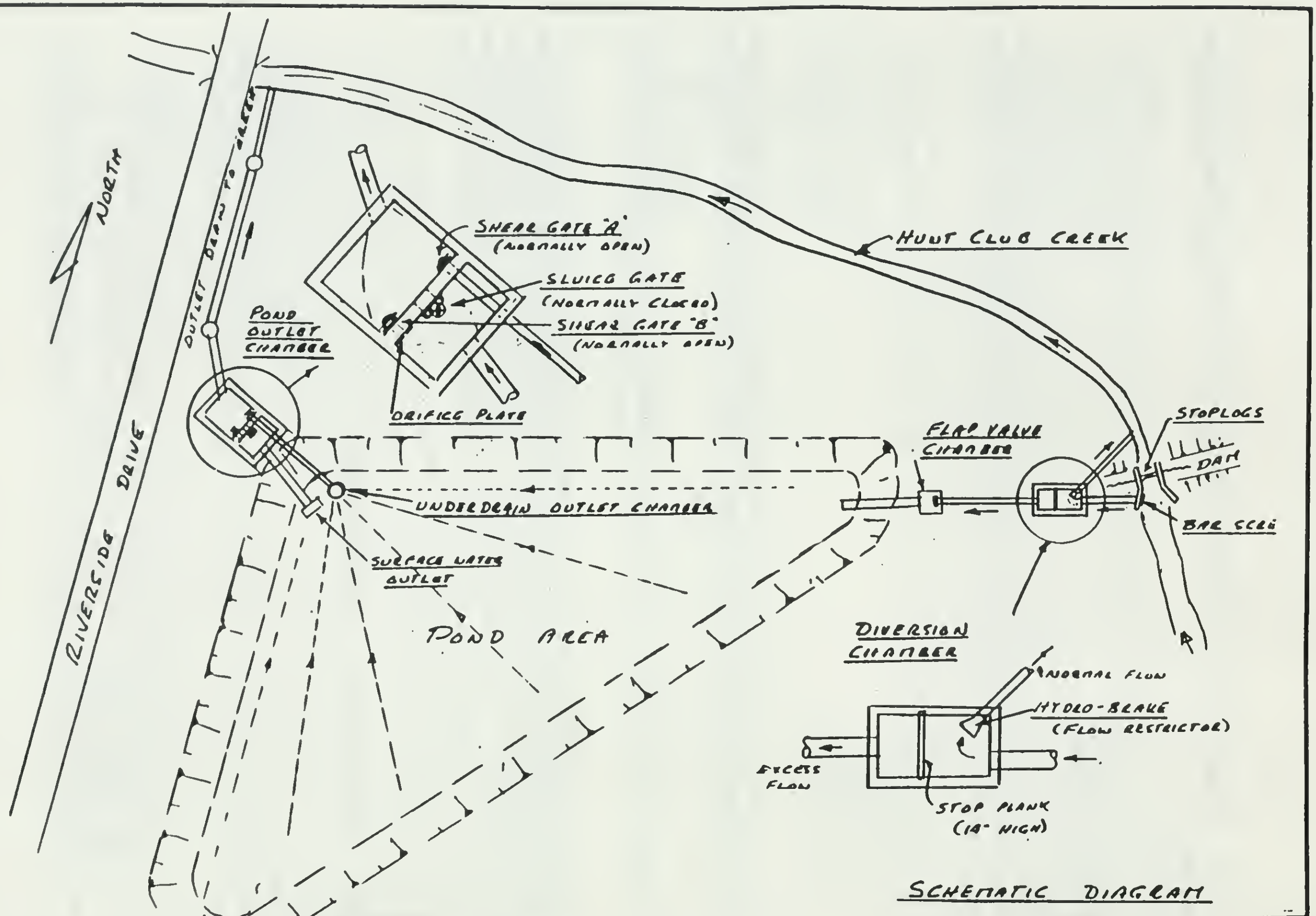
The pond itself is triangular in shape and was designed to detain runoff from a 25 mm rainfall for 72 hours. The storage volume in the pond is 7200 m^3 (Figure 3.11).

The pond was designed to be a dry pond but has the option of operating as a wet pond. Tile drains underneath the pond are controlled at the end of the pipe by a valve. If the valve is opened the pond operates as a dry pond. If it is closed a permanent pool elevation of approximately 1 m is created in the pond. Stop logs can be inserted in the outlet structure to a maximum pond depth of 1.64 metres. The approximate surface area of the pond at the maximum ponding depth is 0.44 ha.

3.16.1 Impact of Uplands Pond on Rideau River

A report was prepared to determine the effect of the Uplands pond on Mooney's Bay (J.L. Richards, 1984). The report was prepared to answer M.O.E. concerns that the slow release of treated water may be more detrimental to swimming conditions at Mooney's Bay Beach than a slug of untreated water. In the analysis the following assumptions were made :

- 1 to 1.4 days travel time from pond to beach
- 90 -95% pond effectiveness for fecal coliform (Kennedy Burnett Report, 1983)
- two design storms (25 mm occurring in either 6 or 10 hours)
- typical Rideau River summer flow of 8 cms
- base wet weather fecal coliform level of 50 /100 ml (monitoring indicated 24 /100



Title
MINISTRY OF THE ENVIRONMENT

UPLANDS POND

Checked	G.B.	Date	JUNE 1990	Job No.	14-90002-101
Drawn	S.M.	Scale	N.T.S.	Figure No.	3.11

ml)
- urban runoff fecal coliform count extrapolated from Kennedy-Burnett monitoring (approximately 10000/100 ml for peak loading and 6000/100 ml for average loading)
- stream flow for the shorter 6 hour storm (higher intensity) was double that recorded for the 10 hour storm (0.42 cms) - bacteria die off rate equal to literature value (43 hours for 90 % die-off (Droste et al., 1982))

Therefore for 24 hours there is a 26 % die-off (logarithmic with time) Hence, the fecal coliform loading without the pond would be :

10000 /ml x 0.42 cms / (8 cms + 0.42 cms)	= 499 /100 ml
- die-off = 0.26 x 499 /100 ml	= -130 /100 ml
+ base fecal coliform	= + 50 /100 ml
	= 419 /100 ml

and the coliform loading with the pond would be :

pond effluent (10 % of average loading)	= 600 /100 ml
with dilution	
600 /ml x 0.054 cms /(8 cms + 0.054 cms)	= 4 /100 ml - die-off = 0.26 x 4 /100 ml
	= -1 /100 ml + base fecal coliform
	= +50 /100 ml
	= 53 /100 ml

Although the report compared the 419 /100 ml to the 53 /100 ml and correctly concluded that the pond had a beneficial impact, the calculations did not strictly answer the original question of the M.O.E.. The calculations provide little insight into the impact of an extended duration of slightly elevated coliform levels versus a pulse of highly elevated bacteria. The analysis also over-estimates the loading without the pond since the same river flow rate is used under storm conditions as under baseflow conditions. The higher coliform levels will be further diluted due to the elevated storm flows. The Ottawa gauge recorded a mean daily flow of approximately 16 cms on November 18 (the original rainstorm). Since the creek flows were doubled for the shorter storm (0.42 cms), one could hypothesize a 50 % increase in Rideau River flows (24 cms) for the shorter storm. Since the flows are daily averages, an average fecal coliform value of 6000/100 ml should be used, not 10000 /100 ml.

These revised figures would transform the "without pond" loading of 419/100 ml to 127 / 100 ml. Although considerably lower, it still cannot match a 90 % removal efficiency.

3.16.2 Uplands Pond Operation and Monitoring

The pond was operated as a dry pond in batch mode during 1986 and most of 1987. The outlet controls (sluice gate, shear gate, and tile drains) were kept closed during dry weather days. Seventy two hours after a storm had occurred the sluice gate was manually opened to discharge the storm runoff. The sluice gate was then closed and the tile drain valve opened for dry weather operation. This mode of operation was called the batch method.

Table 3.10. Removal Efficiencies - Uplands Pond

Storm date	Rain (mm)	TP %	SS %	FC %	Overflow	Retention Time (hr)
1987/06/11	11.80	76	91	98	No	87
1987/06/27	47.60	72	79	95	Yes	144
1987/07/03	12.50	81	92	99	No	81
1987/07/14	21.20	43	57	98	Yes	138
1987/07/24	40.80	75	92	96	Yes	72
Average *	17.60	69	82	97	No	104

* Only the events which did not cause the pond to overflow were averaged

The pond was designed with the influent bypass lower than the effluent overflow such that once the pond was full the remainder of the runoff would bypass the pond. The pond was designed to have the dry weather flow diverted back to the creek via a hydro brake. It was noted in June 1986, that the capacity of the hydro brake needed to be increased, which was done by removing the centre cover plate. Although this allowed dry weather flow to be diverted, the leaking stoplogs within the diversion chamber caused a channel of water to flow into the pond. Six of the seven monitored events in 1986 bypassed the pond.

Rainfall depths over 20 mm caused the pond to overflow. Average retention times in the pond were greater than the recommended value of 72 hours during batch operation in 1987.

The removal efficiency results from the batch mode of operation should be viewed cautiously, however, due to the extensive operational problems with this facility. The pond frequently overflowed due to clogging problems, and the quality of the overflow was not monitored, and as such is not reflected in the removal results.

Operational Problems

The main problem during the two year study at this facility was the maintenance required to ensure efficient operation of the pond. The stoplogs in the dry weather flow diversion chamber always leaked. The shear gate and sluice gate in the effluent chamber needed repairs several times. The leaking from the valves could be enough to drop the water level in the pond by 300 mm overnight.

The greatest problem was keeping the debris and algae in the creek from clogging the influent bar screen. The debris may have been related to the high beaver activity in the creek which was noted throughout the study period. Once the bar screen was blocked by debris the flow would bypass the pond, even when the water level in the pond was low. In 1986 R.M.O.C. staff removed the debris from the grate once of twice per week but this was not often enough to prevent clogging during runoff. In 1987 the debris was removed continually during monitored rainfall events (every hour). This greatly reduced the number of observed bypasses but was manpower intensive.

In addition, homes backed onto the edge of the facility and there were many complaints about the odour, algae, and appearance. As a result the dry weather level was raised in 1987. The performance of the pond was not analysed with the pond operating at the higher level. Concern was also expressed by the homeowners for the safety of the children playing in the area during the high water levels after runoff.

3.17 Other Ontario BMP Facilities

Two other Ontario BMP facilities were discovered from agency contacts which were specifically designed for water quality control. These two facilities were :

- Pickering Plains Wet Pond
- Pine Estates Infiltration Trench

3.18 Pickering Plains Wet Pond

The Pickering Plains wet pond is located in Ajax near Lake Ontario. The pond controls both storm water quantity and quality from a 29 ha residential sub-division.

The pond discharges to Carruthers Creek near an environmentally sensitive marsh.

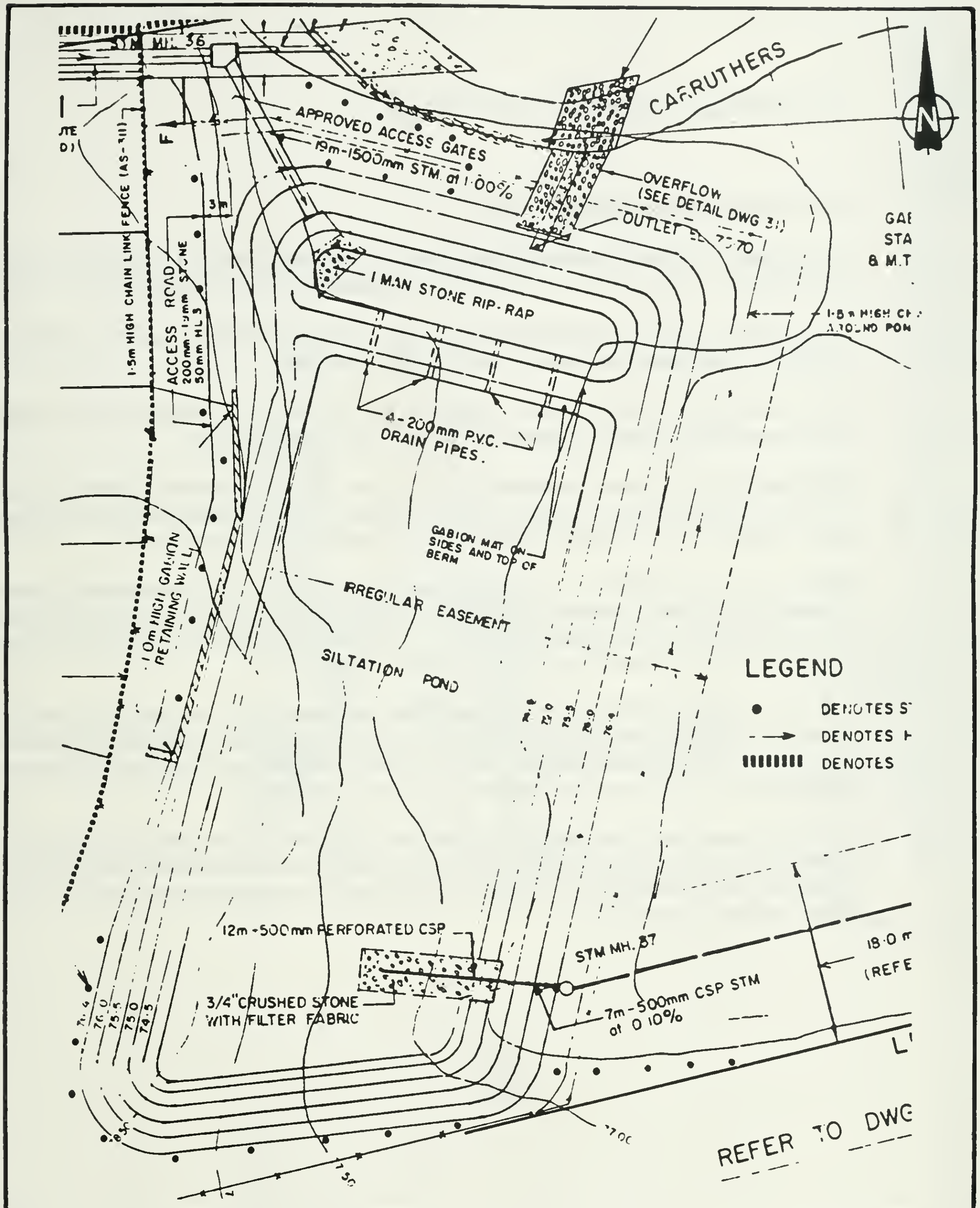
The required volume for the control of the 2 year peak post development flow down to 2 year peak pre-development flow was estimated using OTTHYMO. The required outflows were provided using a weir. Flows in excess of the 2 year storm would be diverted in the storm sewer by an overflow pipe directly to Carruthers Creek.

The volume of quality storage in the pond was designed using the Storage Treatment Overflow Runoff Model (STORM). The pond was originally designed as an extended detention dry pond. The configuration of the pond is shown in Figure 3.12. The STORM model was used to continuously simulate runoff from the catchment for the years 1977 to 1981. The number of pond overflows per year was analysed using different storage volumes and different low flow rates from the extended detention pipe.

The study concluded that a storage volume of 2800 m^3 with an outflow rate of 39 l/s would produce only 2 overflows per year. The effectiveness of this release rate for suspended solids removal was estimated using a ratio of the pond area to the discharge rate (Tapscott, 1980, Wisner, 1986). The estimated effectiveness based on this ratio was approximately 95-99 %.

Inflow to the pond was uniformly distributed by four 200 mm pipes in a 0.5 m baffle at the upstream end of the pond.

The pond currently operates as a wet pond. The reason given for the inoperable extended detention pipe is that there is a lack of gradient from the pond water surface to the creek (Personal comm. with M. Simms, 1990). Another reason may be that the pipe has become clogged with sediment. This could have occurred for numerous reasons (poor construction techniques, heavy sediment loading during sub- division construction, etc.).



Title MINISTRY OF THE ENVIRONMENT PICKERING PLAINS POND	882-1100		
	Checked G.J.B.	Date JULY 1990	Job No. 14-90002-101
	Drawn K.J.G.	Scale N.T.S.	Figure No. 3.12

No monitoring has been conducted on this pond.

3.19 Pine Estates Infiltration Trenches

Pine Estates is an estate residential sub-division (70 ha) which drains to a tributary of the Credit River. Thirty hectares of this land is designated as private open space.

Runoff from the site was estimated using both the Rational Method and the MIDUSS program. The highest flow values were used in the analysis.

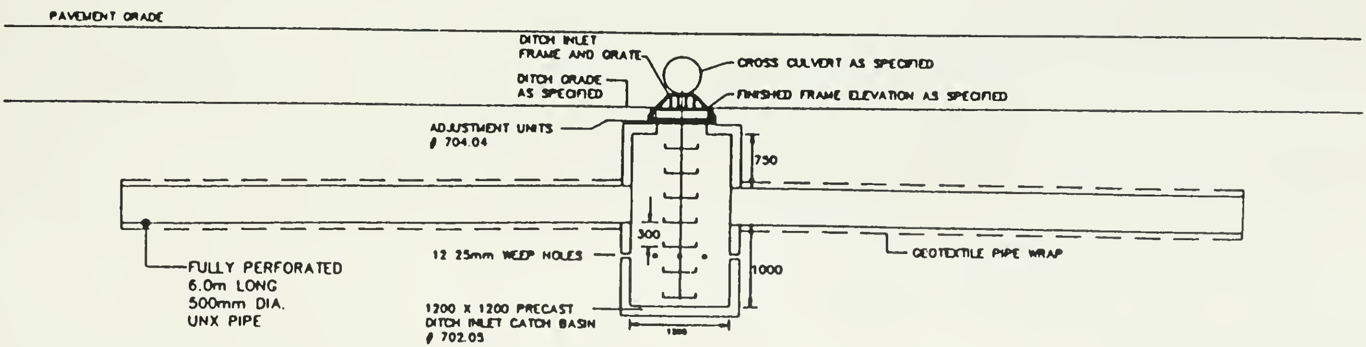
The sub-division, which was built in 1988-1989, incorporates runoff quality source controls such as roof leaders which drain to the sub-soil via a perforated pipe.

Infiltration structures were constructed at major ditch outlets to collect and infiltrate storm water. A plan of one such structure is given in Figure 3.13. Two structures were provided at each internal cross culvert location due to increased flows in these areas.

Field tests were conducted on a prototype structure to determine the effectiveness in flow control. Initial testing showed an exfiltration rate of 0.03 m^3/s. The prototype was tested 5 days later with an exfiltration rate of 0.01 m^3/s (excavation material was discovered in the structure from the installation of a road cross culvert).

The report concluded that with proper installation and protection of the structures, until the area was stabilized, the original exfiltration rate of 0.03 m^3/s was reasonable. Based on these rates the infiltration structures and roof leader controls were able to control the post development runoff to pre-development rates for a 5 year storm.

A field investigation of these structures (1990) revealed that the oldest infiltration structures have become plugged with sediment. The lack of any pre-treatment technique to trap large sediment particles before flow reached the structures is undoubtedly responsible for the early failure of these BMPs.



Title: MINISTRY OF THE ENVIRONMENT PINE ESTATES INFILTRATION STRUCTURE	Checked G.J.B.	Date JULY 1990	Job No. 14-90002-101
	Drawn K.J.G.	Scale N.T.S.	Figure No. 3.13

Appendix D

BMP WORKSHOP ATTENDEES

J. Antoszek	- Ministry of Environment
J. Bennett	- Marshall Macklin Monaghan Limited
R. Bishop	- Marshall Macklin Monaghan Limited
G. Bryant	- Marshall Macklin Monaghan Limited
R. Claytor	- Loiederman Associates
D. Greer	- Ministry of Natural Resources
D. Henry	- Ministry of Environment
B. Hindley	- Metropolitan Toronto Region Conservation Authority
I. Kulnieks	- Ministry of Environment
K. Loftus	- LGL Limited
D. Mack-Mumford	- Town of Markham
J. Marsalek	- Environment Canada (CCIW)
N. Mather	- Urban Development Institute
N. McLeod	- Marshall Macklin Monaghan Limited
L. Pella	- Ministry of Natural Resources
J. P'ng	- Ministry of Environment
E. Salenieks	- Marshall Macklin Monaghan Limited
T. Schueler	- Metropolitan Washington Council of Governments
M. Schollen	- Marshall Macklin Monaghan Limited
M. Seto	- Ministry of Environment
W. Snodgrass	- Beak Consultants
J. Tran	- City of Scarborough
R. Webb	- Marshall Macklin Monaghan Limited
M. Weaver	- Ministry of Transportation
P. Wisner	- Wisner and Associates
W. Wong	- Ministry of Transportation

AGENDA OVERVIEW

BMP/WATER QUALITY POND WORKSHOP

April 18 & 19, 1990

DAY 1

9:00	Introduction/Coffee
9:15	Review of Objectives of Workshop
9:30	Overview of Current BMP/W.Q. Pond Technology
10:30	Overview of Effectiveness
11:30	Review of Canadian Concerns/Differences
12:00-1:00	Lunch
1:00-3:00	SESSION 1 Design Considerations (Objectives, Criteria, Selection Methods, Benefit - Cost) Moderators: B. Snodgrass R. Claytor
3:00-3:15	Coffee
3:15-4:30	SESSION 2 Planning/Approval Process Moderators: J. Bennett B. Hindley

AGENDA OVERVIEW

BMP/WATER QUALITY POND WORKSHOP

April 18 & 19, 1990

DAY 2

9:00-9:30	Summary of Group Discussions from Day 1
9:30-10:45	SESSION 3 Environmental Issues Moderators: K. Loftus J. Imhoff
10:45-11:00	Coffee
11:00-12:00	SESSION 4 Operations/Maintenance/Public Concerns Moderators: N. Mather J. Tran
12:00-1:00	Lunch
1:00-2:00	SESSION 5 Research Needs/Pilot Projects Moderators: J. P'ng J. Marsalek
2:00-2:30	Chairmens' Reports from Working Groups
2:30-3:00	Coffee
3:00-4:00	Wrap-up

BEST MANAGEMENT PRACTICES DETAILED AGENDA (APRIL 18 & 19)

REVIEW OF WORKSHOP OBJECTIVES

- To define the applicability of BMPs with respect to water quality objectives, land use planning, climate, etc.
- To define the planning/implementation framework for BMPs in Ontario
- To define the design methodology for BMPs
- To define BMP operational/maintenance/public concerns
- To define gaps in BMP technology, and research/monitoring needs

OVERVIEW OF CURRENT BMP TECHNOLOGY

Goal - To define the status of BMP technology

- 20 minute presentation - U.S. experience with BMPs and current status of storm water quality programs in Maryland

- 20 minute presentation - Ontario experience with BMP facilities and status of storm water quality regulations

- Discussion - experience from other geographic areas
  - disinfection
  - "soft" BMPs (planning)

OVERVIEW OF BMP EFFECTIVENESS

Goal - To determine BMP effectiveness and limits of confidence

- 20 minute presentation - U.S. NURP study
  - current receiving water studies

- 20 minute presentation - Canadian/European information on BMP effectiveness

- 20 minute discussion - use of effectivenesses in BMP design
  - monitoring inaccuracies

CANADIAN CONCERNS/DIFFERENCES

Goal - To define areas of concern due to Canadian conditions

Potential Topics....

What impact will 3 (or 4) levels of government have on the design/approval process of BMPs ?

What impact will the Canadian climate have of BMP design ?
- Aggregation of snowmelt pollution and first flush effect
- Accumulation of chlorides from road salt and effect on BMP ecosystem/removal process
- frozen ponds and infiltration trenches
- Effect of shorter growing season on nutrient removal and vegetation establishment

What impact will Canadian soils/physiography have on BMP selection ?
- Regional differences in BMP selection methodology due to Canadian Shield
- Buffering capacity of southern Ontario soils to acidic precipitation versus non-buffering northern Ontario soils

What impact will the Canadian land use practices have on BMP implementation ?
- use of stormwater dry detention ponds for baseball fields (ponds located in open space designation; subsequent problem in retrofit situation)

How will municipal practices (eg. 1200 mm cover on pipes) affect BMP feasibility in areas without suitable topography ?

What effect does the lack of incentives for BMP implementation (such as flood insurance eligibility in the U.S.) have on the use of soft (planning) BMP approaches ?

DESIGN CONSIDERATIONS

Goal - To determine a design philosophy, and the parameters on which to base BMP designs

Potential Topics....

Should receiving water quality criteria, or 'best available low-cost technology' dictate the design criteria for BMPs ?

How do the objectives/criteria of M.N.R., M.O.E., the municipality and the C.A. affect the BMP design criteria ?

Should the emphasis be placed on providing regional BMP facilities as opposed to local facilities ?

Specific Design Consideration

What are the main parameters/constraints ?

- type of development
- class of receiving waters
- physiography/topography
- soils/geology
- climate
- safety
- maintenance
- cost
- aesthetics
- effectiveness of BMP re. different pollutants
- environmental impacts

Is there a potential conflict between quantity design criteria and quality design criteria ? Where are criteria deficient ?

(Each type of BMP should be reviewed re. maximum effectiveness vs. constraints, particularly physical, cost, etc. Other constraints such as environmental will be reviewed in detail in later sesssions.)

PLANNING/APPROVAL/MONITORING PROCESS

Goal - To define a framework for the planning, and approval of BMPs

Potential Topics....

Is the planning model in the Urban Drainage Guidelines acceptable for BMP implementation ?

What agencies are responsible for BMP approval ?

Is there a way to streamline or improve the planning/approval process ? Should one agency take a leading role in the process ?

Who is responsible for monitoring the effectiveness of BMPs and enforcement of water quality criteria compliance ?

How long should the developer be responsible for the effectiveness of a BMP ?

What tolerance in BMP effectiveness is allowable when assessing water quality criteria compliance ?

ENVIRONMENTAL ISSUES

Goal - To identify the environmental impact concerns of BMPs on receiving waters and surrounding ecosystem

Potential Topics....

What is the scope of concern ? (ie. Even though the immediate receiving waters may be of low quality potential should protection of the ultimate receiving waters determine the quality criteria ?, sustainable development, ecosystem approach to water management)

What is the net effect of BMPs on the receiving waters quality ?

Is there a need to refine the relationship between pollutant control and environmental protection/enhancement ?

How does the downstream watercourse classification affect BMP selection/implementation ?

How do the interim storm water quality guidelines affect BMP selection/implementation ?

What impacts will BMPs have on their surrounding areas ?

What are the long term effects of stormwater pollutants on intended plant life and wildlife ? (ie. salt on plants, spill containment on wildlife) Is the BMP design compatible with the potential pollutants ?

Should trade-offs be made in the implementation of BMPs ? (ie. should existing land be excavated (destroy current ecosystem to provide downstream protection ?) (implement wet ponds upstream of cold water fisheries)

OPERATIONS/MAINTENANCE/PUBLIC CONCERNS

Goal - To identify the operations and maintenance concerns regarding BMPs and public acceptance of BMPs

Potential Topics....

Who will inspect and maintain the BMP facilities ?

How will BMP maintenance be funded ?

What costs are associated with BMP monitoring/maintenance ?

How significant would problems such as aesthetics, algae, and mosquitos be in BMP facilities?

What are the potential pollutant accumulation/disposal problems associated with BMPs ?

What impact will legality concerns have on BMP design ? (fences, pond depths)

RESEARCH NEEDS/PILOT PROJECTS

Goal - To identify areas requiring research and necessary pilot studies

Potential Topics....

In what areas are BMPs not well documented in terms of effectiveness for Canadian conditions ?

What is required to establish a database on long term performance/maintenance needs and associated costs ?

What environmental effectiveness monitoring is required ?

Are there current or planned BMP implementations which could serve as pilot projects ?

WRAP UP

Goal - To summarize/evaluate limitations of workshop

Potential Topics....

What conflicts were discovered between the 2 working groups ?

What topics were identified that were not identified on the workshop agenda ?

What recommendations from the workshop are to be included in the report ?

6.0 BMP WORKSHOP PROCEEDINGS

6.1 INTRODUCTION

A Workshop on BMPs and Water Quality Ponds was held on April 18 and 19, 1990 at the Parkway Sheraton Hotel in Markham.

The goal of this Workshop was to bring together representatives of provincial government agencies, municipalities, universities, consultants, etc. to discuss the BMP planning and design process as it applies to Ontario. The aim was to obtain input to the study from a wide range of experts/designers/approvers of water quality controls associated with development.

The following sections of this appendix document the presentations and discussions held over the two day period based upon rates kept by reporting secretaries for each session.

For the main sessions, two working groups were formed. The following separately reports the discussions of each group. The key points from the Workshop have been brought forward into the main report.

6.2 OVERVIEW OF CURRENT TECHNOLOGY

Maryland, U.S.A.

An overview of current BMP implementation in Maryland U.S.A. was provided by Mr. R. Claytor. In 1977 mandatory storm water quantity regulations were instituted for urban developments. Storm water quality regulations were implemented in 1984. The impetus for quality guidelines in Maryland arose form the degradation of the Chesapeake Bay from urban development. The continuing degradation of water quality once point sources had been controlled, alluded to the requirement of non-point source controls in this watershed.

A hierarchy of best management practices are reviewed for storm water quality control during the planning of an urban development. The BMPs are assigned a priority in terms of preference for pollutant removal :

1. Infiltration techniques
2. Vegetative techniques
3. Retention facilities (wet ponds)
4. Detention facilities (dry or extended detention ponds)

Mr. Claytor then reviewed the various types of BMPs in use in Maryland discussing design features using slides to show examples.

Ontario BMPs

Mr. G. Bryant described examples of a number of BMPs which were discovered through contacts with various agencies during the initial stages of the study. These included :

- Pickering Plains	- wet pond/ marsh infiltration system
- Tapscott Pond	- wet pond
- Pine Estates	- infiltration system
- Lake Aquitaine	- wet pond
- Lake Wabukayne	- wet pond
- Steeles L'Amoureaux Park	- wet pond
- Valleywoods	- wet ponds
- Region of Ottawa-Carleton	- wet ponds

The Ottawa-Carleton ponds, Lake Aquitaine, Lake Wabukayne, Pine Estates infiltration system, and Pickering Plains wet pond are described in detail in Appendix C.

6.3 EFFECTIVENESS OF CURRENT TECHNOLOGY

Mr. T. Schueler of the Washington Council of Governments gave an overview of the effectiveness of various types of technology. He noted that effectiveness not only includes efficiency of pollutant removal, but also extent of service life, degree of impact on the environment, and public acceptability. Mr. Schueler presented various overheads to illustrate his discussion which are included as Figures 6.1 to 6.6 and Tables 6.1 to 6.4. These indicate:

- variations of detention time with event frequency for a single outlet of an extended detention facility
- long term removal efficiency for various monitored facilities
- event based efficiencies for an example facility
- the partitioning of storage in a typical extended detention system
- variations on the design of extended detention systems
- considerations related to streambank erosion/bankfull flow
- a sketch of the ultimate BMP Concept Plan

Mr. Schueler completed his discussion by illustrating a number of design considerations using slides of example facilities.

Relationship between Detention Time and Storm Events for a Single Oriface ED Facility*,**

Frequency/inches	Inflow (cfs)	Outflow (cfs)	Detention Time (hours)
3 months/ 0.6	0.93	0.45	1.2
6 months/ 1.3	8.4	0.75	8.4
1 year/ 2.6	28.7	1.30	18.4
2 years/ 3.2	45.2	6.60	9.4
5 years/	76.0	27.9	3.8

*Design based on detaining runoff from one-year storm for 24 hours
**Source: study conducted by William Stack, Pollution Control Supervisor, Department of Public Works, Ctiy of Baltimore.

TABLE 6.1

Relationship between Detention Time and Storm Events for Various Outlets used in ED Facilities(1,2)

Frequency/inches	Inflow (cfs)	Outflow (cfs)	Single(3) Dt (hours)	Multi(4) Dt (hours)	Multi(5) Dt (hours)
3 months/ 0.6	0.93	0.45	1.2	2.8	6.0
6 months/ 1.3	8.4	0.75	8.4	11.6	12.4
1 year/ 2.6	28.7	1.30	18.4	18.4	18.4
2 years/ 3.2	45.2	6.60	9.4	9.4	9.4
5 years/	76.0	27.9	3.8	3.8	3.8

(1) Design criteria: must detain runoff from one-year storm for 24 hours
(2) Source: William Stack, Pollution Control Supervisor, Department of Public Works, City of Baltimore.
(3) Outlet device: single 4 inch oriface
(4) Outlet device: perforated riser with 16 1 inch holes placed over three foot interval in riser
(5) Outlet device: perforated riser with 64 1/2 inch holes every 6 inches at 8 different levels

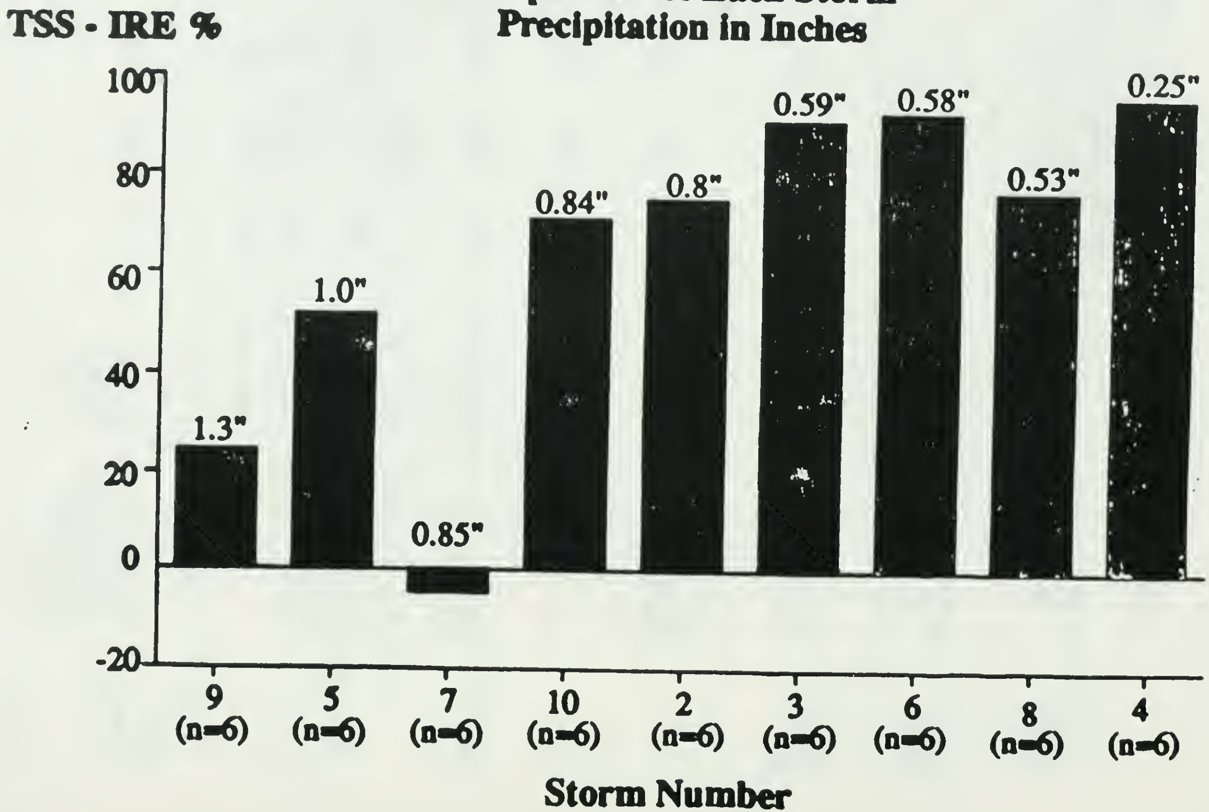
TABLE 6.2

LONG TERM BMP POLLUTANT REMOVAL RATES

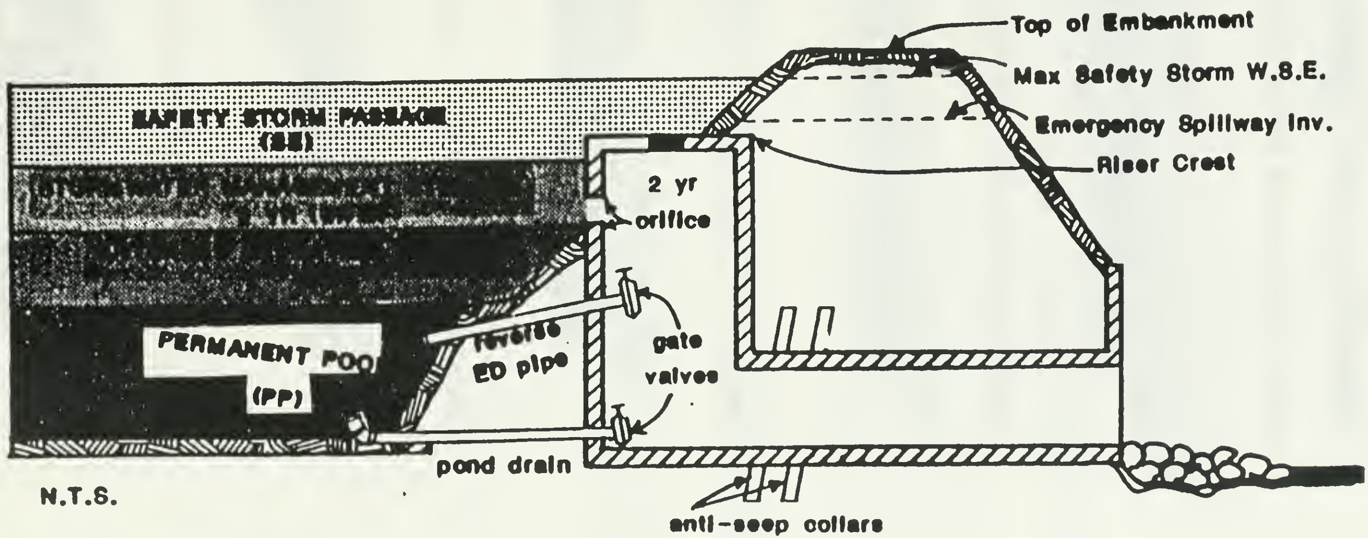
POND TYPE	SITE NAME	DESIGN CRITERIA	LONG-TERM MASS REMOVAL RATE					
			TSS	TP	TN	COD	Zn	Pb
DRY POND	Lakeridge	Two Year SWM Only	14	20	10	0	-10	ND
DRY ED POND	Stedwick	6-12 hrs of ED	70	13	24	27	57	62
	London Commons	a. 4-6 hrs of ED	29	40	25	17	25	29
		b. 6-12 hrs of ED	74	56	60	41	40	24
	Oak Hampton	6-18 hrs of ED	73	35	--	--	--	--
	Settling Column Tests	a. 12 hrs	68	42	25	35	--	72
		b. 24 hrs	75	45	32	39	--	81
		c. 48 hrs	85	50	39	54	--	85
WET PONDS	Burke/ Westleigh (pooled)	VB/VR Ratio 8:1	54	66	28	30	51	65

TABLE 6.3

Instantaneous Removal Efficiency (IRE)
Comparison of Each Storm
Precipitation in Inches



Cross-Section of the Extended Detention Pond System

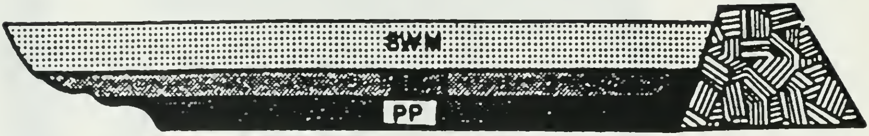


N.T.S.

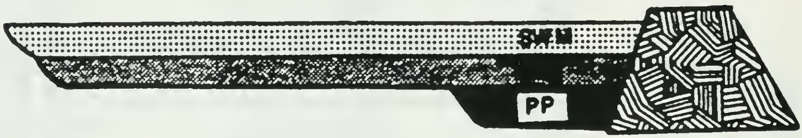
FIGURE 6.2

Design Variants of the Extended Detention Pond System

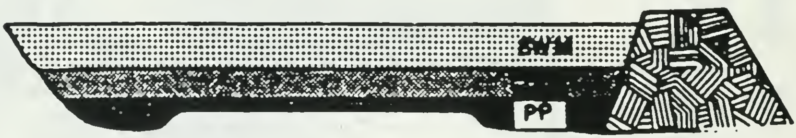
Design No. 1: Standard Wet ED System



Design No. 2: Undersized Pool w/ED



Design No.3: Shallow Marsh w/Forebay



Design No.4: Oversized Pool w/no ED

Design No.5: Water Quality BMP w/no SWM

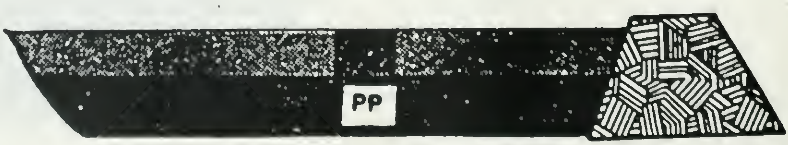


FIGURE 6.3

STREAMBANK EROSION CONTROL CONSIDERATIONS

A. HISTORICAL STUDIES HAVE SHOWN THAT 1.5 to 2 YEAR RETURN FREQUENCY STORM CONTROLS THE SHAPE AND FORM OF NATURAL CHANNELS

B. THE TWO YEAR OR BANKFULL FLOOD IS MOST EROSIVE STREAM CONDITIONS

C. ALL LOCAL POLICIES CALL FOR CONTROL OF THE MAGNITUDE IN THE POST DEVELOPMENT 2 YEAR BANKFULL FLOOD (to predevelopment conditions)

D. BUT DO NOT ADDRESS THE INCREASE IN FREQUENCY OF THE 2 YEAR BANKFULL FLOOD

E. WHILE LITTLE RESEARCH IS AVAILABLE; LOCAL EXPERIENCE INDICATES THAT 2 YEAR MAGNITUDE CONTROL, BY ITSELF, IS NOT OFTEN ADEQUATE TO PROTECT DOWNSTREAM CHANNELS.

F. COG THEORETICAL MODEL INDICATES THAT ED STORAGE OF RELATIVELY SMALL RUNOFF VOLUME CAN SHARPLY DECREASE THE ADDED FREQUENCY OF BANKFULL FLOODING.

TABLE 6.4

URBANIZATION and STREAM CHANNEL GEOMETRY

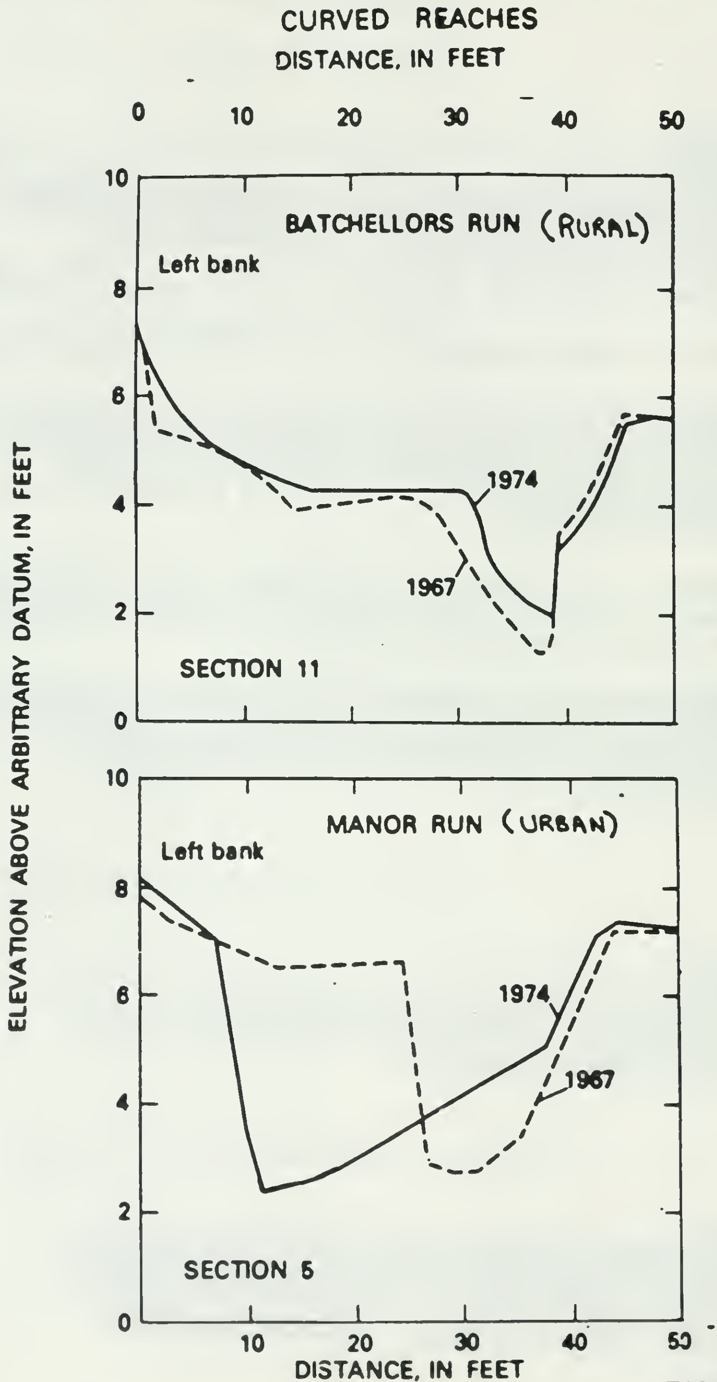


FIGURE 6.4

Frequency of Bankfull Flooding As a Function of I

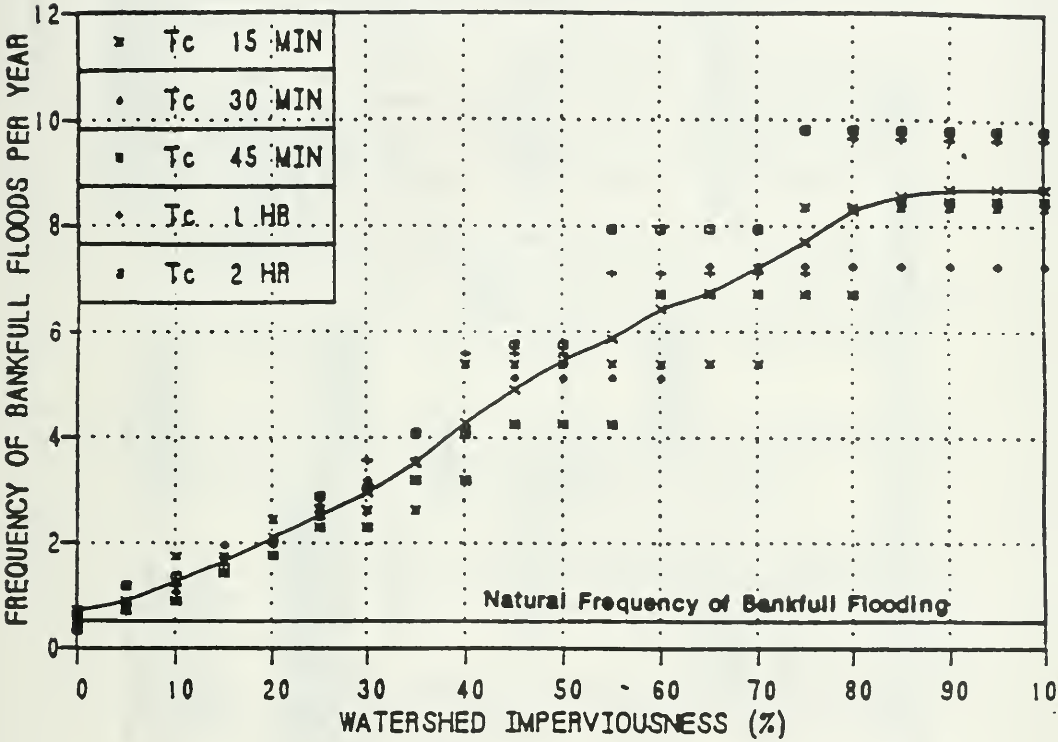
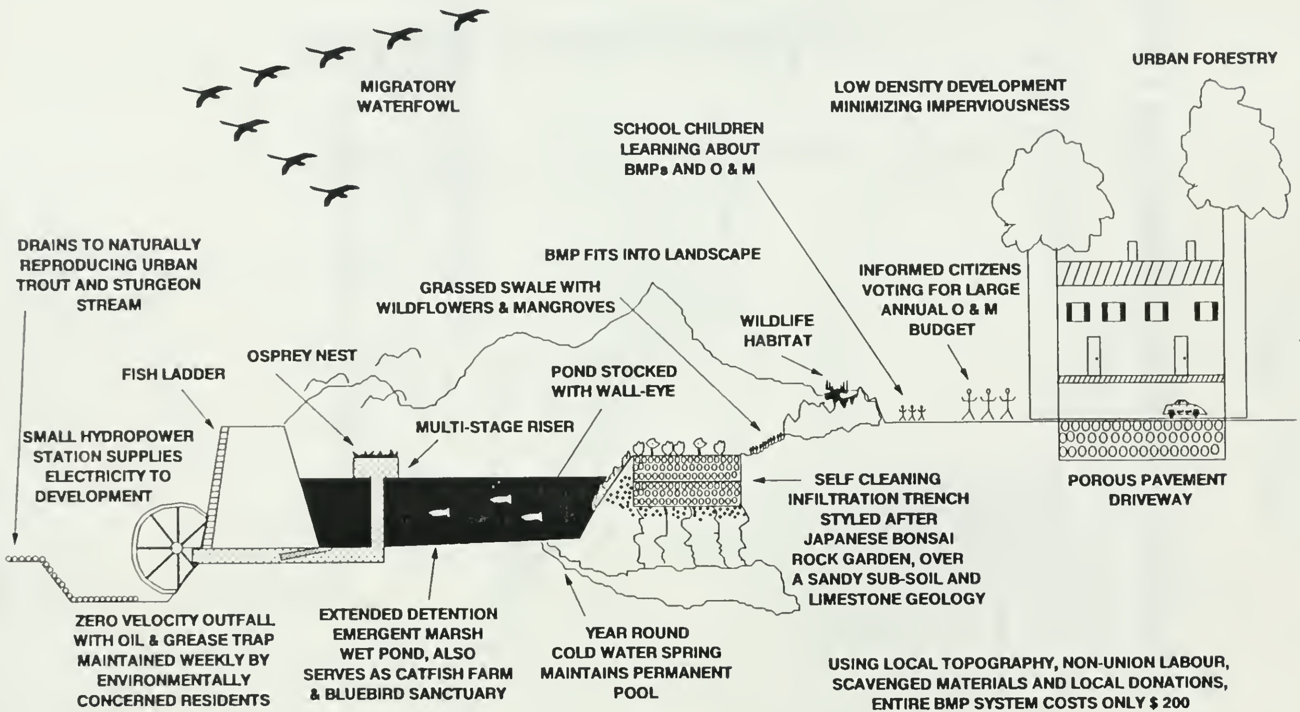


FIGURE 6.5

FIGURE 6.6 ULTIMATE BMP CONCEPT PLAN



(SCHUELER, TRS-MWCOG, 1986)

6.4 CANADIAN CONCERNS

The following section describes the Canadian concerns which were identified regarding BMPs due to the differences between Canada and the United States.

1. There are four (4) levels of government involved in the planning and approval stages of storm water quality controls (Ministry of Natural Resources, Ministry of Environment, Conservation Authority, and Municipality).

2. Certain municipal practices in Canada differ from Maryland. It is customary for Canadian municipal engineers to require 1200 mm cover on all storm sewer pipes. This cover necessity often precludes the use of surface ponds within developments on the tablelands. Most Ontario ponds are located in the valleylands due to the requirement to meet grade on the pipe system.

3. The funding of projects differs in Canada from the States. There is less government funding of projects in Canada than in Maryland. The political climate of Washington D.C. plays a large part in being able to obtain funding for non-point source pollution control studies. The funding of urban storm water quality studies in Canada comes from private developers in the development process.

4. Canada has a higher percentage of cold water streams. The protection of these streams requires mitigative measures in upstream areas. In this scenario, storm water quality controls would be required throughout a watershed.

5. Canadians expect to use streams for body contact recreation (swimming). In Maryland the public accepts the loss of swimming privileges in their waterways. The control of bacteria (for body contact) requires a higher level of storm water quality control.

6. Generally, higher density development occurs in Ontario than in Maryland. This implies that the U.S. pollutant loading rates, and hence sizing rules, for BMP design may not be transferable to Ontario.

7. The sediment and erosion controls during construction are more stringent in Maryland than in Ontario. Unless similar controls are placed in Ontario, online storm water quality facilities will be subject to greater sediment loads in developing watersheds.

8. In Maryland there is a distinct separation between storm water land use and park land dedication. In Ontario, storm water facilities tend to be placed in parkland areas, since the majority of facilities implemented to date have been

dry quantity ponds. The effect of retrofitting dry ponds for wet quality ponds would preclude the use of the parkland for recreation.

9. The climate of Ontario is different from Maryland. The majority of Ontario watersheds are subject to a heavy volume of runoff during the spring freshet. The utility of infiltration techniques during this period is questionable since the upper soil zone would be either frozen or saturated. Pond operation during ice conditions has not been well documented and gives further rise to questions concerning BMP effectiveness during periods of spring runoff.

6.5 DESIGN CONSIDERATIONS

The Design Considerations session was held to determine the participants' views on BMP design philosophy. The parameters on which to base the design were discussed, as well as some deficiencies in the current water quality criteria (or lack of) which must be overcome to ensure uniformity across the province.

Group 1

The following major points were identified by Group 1:

There was a consensus that the BMP design should be based on downstream water uses.

A system of stream classification, similar to the one in Maryland, is required for Ontario watercourses.

Class I - estuaries
Class II - contact recreation
Class III - reproductive trout
Class IV - put/take fishery

The classification system could be defined by 3 levels of sensitivity :

- low
- medium
- high

The level of water quality protection should be made on a watershed basis because of varying uses :

- swimming
- cold water fisheries
- recreation
- water quality for the sake of water quality

The idea of water quality improvement for the sake of improvement was not supported by the entire group.

The general level of BMP protection should be identified during the Master Drainage Plan or Secondary Plan level. The final selection of actual BMPs should be left to the local level.

Additional factors besides downstream water uses need to be considered during the design stage of BMPs :

- spill control
- safety
- aesthetics
- multi-use
- maintenance
- cost

The selection and design of a particular BMP must consider both acute/toxic levels and cumulative effects in the watercourse system to ensure that an adequate level of protection is provided.

Municipalities have a philosophical problem which must be overcome, in order for municipalities to accept the responsibility and liability concerning BMPs. The lack of policy on storm water quality has predicated jurisdictional problems concerning the responsibilities/ liabilities of the different approval agencies.

Technological problems with regards to BMPs to control water quality from transportation corridors were identified :

- transportation development is ribbon development which does not lend itself to centralized BMPs
- infiltration techniques may damage highways

Maryland highways are generally not serviced by BMPs. Instead, money is provided by the Department of Transportation towards the construction of a regional BMP facility.

Agricultural considerations must be included in the planning of water quality measures to effectively protect a natural watershed.

Soft BMPs such as down-zoning and fertilizer control should be used in conjunction with BMP facilities. Soft BMPs are frequently used in the state of Maryland.

It was recognized that the design philosophy must consider long term needs such as funding for maintenance.

Group 1 was asked whether the design process could be tailored after Schueler's U.S. manual. It was noted that snowmelt quality and volume, and ice effects on ponds, were additional issues which had to be addressed in the Canadian design process.

General considerations involved in the BMP design process in Maryland were presented. The group agreed that these were the necessary steps involved in the BMP design process. The steps can be summarized as follows :

IDENTIFY SITE SPECIFIC CONCERNS

- Stream classification
- Stream buffers
- Wetlands
- Proximity to residences
- Maintenance access
- Priority based on state/(provincial) law
- Downstream constraints
- Downstream houses
- Soils survey
- County zoning and master plan
- SWM control requirements

SCREEN BMPs BASED ON LEVEL OF PROTECTION

SCREEN BMPs BASED ON SITE CONDITIONS

Group 2

The main points from the discussion in group 2 can be summarized as follows :

Design considerations should be based on water use which would require the adoption of a stream classification system.

There is no agreement among the reviewing agencies on uniform water quality effluent criteria. The lack of agreement stems from the different interests/concerns of the involved agencies.

The following factors should be reviewed during the design/selection of a BMP :

- desired level of water quality protection
- required level of water quantity control
- existing habitat concerns
- aesthetics/integration of BMP into the existing environment
- protection and establishment of riparian/terrestrial vegetation and requirements for shading
- degree and ease of maintenance
- degree of development
- construction sediment and erosion control measures

There is a need for a long range approach to water quality designs. This long range approach would involve incremental changes to existing designs, and the implementation of a retrofit program.

There should be a greater emphasis on source control measures as opposed to end of pipe solutions. Examples of source control measures would be :

- greater public information/awareness on non-point source pollution (eg. pet droppings)
- stringent MOE controls on pesticides and fertilizers
- stringent MTO controls on vehicle emissions and scheduled maintenance

Pilot projects are required on infiltration structures and wet ponds to determine their performance under snowmelt and ice conditions. The wet pond technology from Maryland should be more transferable than the infiltration techniques.
A list should be compiled on what land uses are incompatible with the different BMPs.

A probablistic approach (number of violations per year) should be used in the design of BMPs as opposed to stating a removal efficiency based on a certain design storm.

Some water uses (ie. swimming) require a level of treatment which is higher than that attainable with BMPs. Other treatment technologies such as ultra-violet disinfection or ozonation should be investigated for the protection of swimming areas.

In certain instances, the level of water quality protection cannot be attained with the use of BMPs due to the density of the development itself. Areas where the intended land use is incompatible with the water use should be identified at the master drainage plan level.

6.6 PLANNING / APPROVALS PROCESS

In this session the groups reviewed the planning and approvals process for stormwater management. The goals of this session were to determine whether the current processes are adequate for BMP implementation, and if not, what improvements could be made to expedite the planning/approvals process.

Group 1

Group 1 discussed 6 major topics in this session :

- Administration of BMP Approvals
- Implementation of BMPs
- Municipal Perspectives
- Developer Responsibility
- BMPs in Existing Areas
- Land Use Considerations

1. Administration of BMP Approvals

In Maryland the state sets an overall storm water quality policy which it delegates to the local municipalities for implementation. The individual municipalities implement their own storm water quality criteria based on state policy. The municipality programs are reviewed every two years by the state to ensure compliance and uniformity.

There was some conflict within the group as to whether the current review and approvals system in Canada is adequate. There was a consensus that a clear policy on storm water quality was lacking. A clear policy statement was thought to be ineffective, however, since a mechanism for the enforcement of the policy was not in place.

The strategy in Canada would be to get provincial involvement (MOE, MNR) at the Official Plan and Secondary Plan level. The municipality would then administer the water quality requirements at the site plan level.

It was recognized that there was a need for detailed design objectives and standards for storm water quality. These standards would facilitate the BMP approvals process.

2. Implementation of BMPs

The Planning model outlined in the Urban Drainage Design Guidelines (Figure 6.7) is appropriate in theory for the implementation of BMPs. In reality several conflicts have to be resolved :

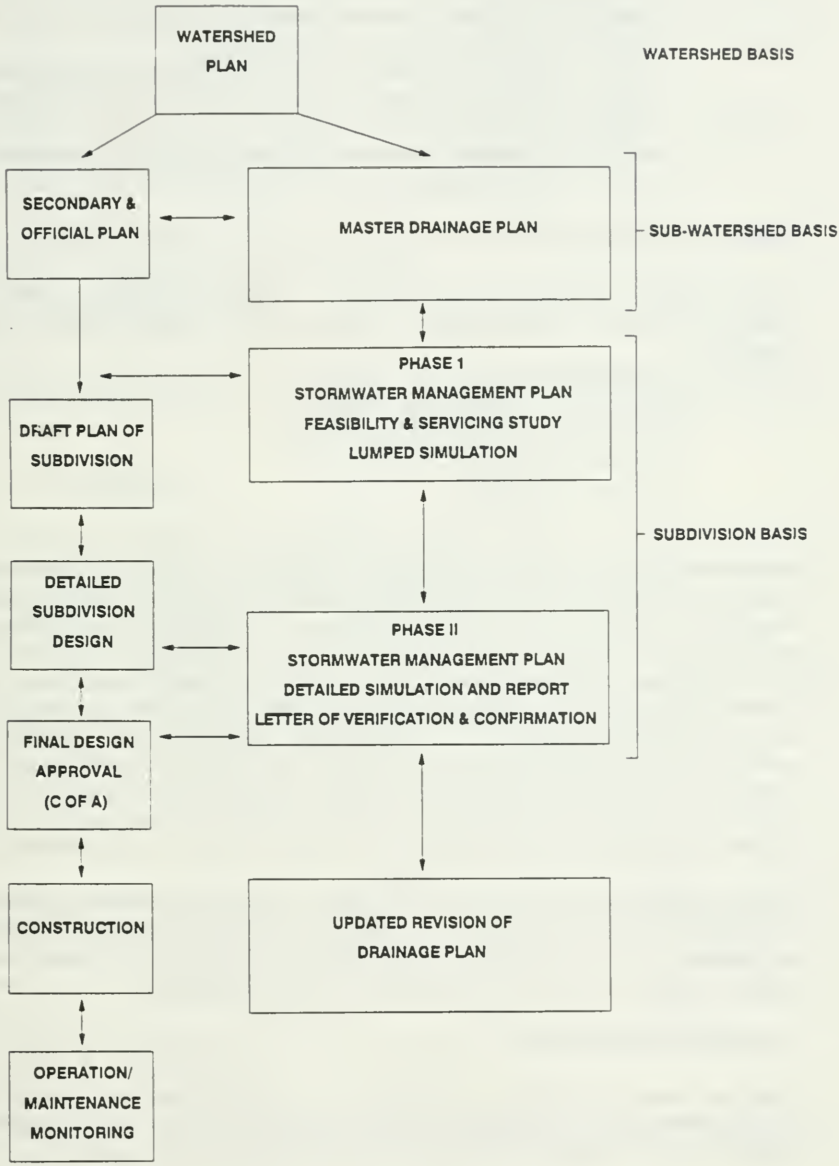


FIGURE 6.7 URBAN DRAINAGE AND LAND USE PLANNING FOR NEW DEVELOPMENT

- who provides funding for MDP studies
- timing of BMP planning versus current development pressures
- problems with trans-boundary jurisdictions
- Master Drainage Plans do not provide enough water quality detail. Master Drainage Plans should address water quality concerns to the point of dictating allowable land use planning.
- there is no provincial requirement for the preparation of Master Drainage Plans and their inclusion in the Official Plan.

3. Municipal Perspectives

The discussion of municipal perspectives raised a number of questions, mostly on the topic of BMP operations/maintenance funding. Several methods of BMP funding were discussed :

- a development charge
- performance bonds on development
- money in lieu of major system control
- community covenants on BMPs
- a storm water utility

It was acknowledged that the municipality's reluctance to become involved in water quality planning/control stemmed from the historical perspective of storm water and the municipality's historical role in pollution control. It is only recently that storm water has been targeted as being a major source of pollution. Traditionally, sewage and water works have been dealt with at the Regional Municipality level. Storm water was previously thought to be a nuisance of development which needed to be drained from the site as quickly as possible. Since storm water was thought to be clean, the local municipalities were delegated the responsibility of ensuring that conveyance of storm water to a watercourse was provided. Some municipalities believe that the recent requirements for storm water quality control make BMPs the responsibility of the regional municipality who have traditionally dealt with water quality problems.

The group agreed that it will be a tough task to convince municipalities that they should be responsible for the operation and maintenance of BMPs after the developer's bonds are released. It was also agreed that the inclusion of water quality criteria along with quantity criteria will burden the planning and approvals process.

4. Developer Responsibility

Developer funding for BMPs was recognized as a necessary part of new developments. The length of time the developer should be responsible for the operation/maintenance of BMPs was not agreed upon.

In order to gain the support of the development industry it was recognized that there must be a clear definition and consistent application of storm water quality requirements.

The use of the 5 % parkland dedication for BMPs was discussed.

It was hypothesized that the development industry could be encouraged to implement BMPs on the basis of marketing benefits of certain BMPs such as wet ponds for recreation and aesthetics.

The group concluded that the development industry should be involved in the establishment of storm water quality requirements.

5. BMPs in Existing Developed Areas

The same design process could be utilized for re-development as new development. Public funding will be required in existing areas designated for retrofitting water quality controls.

6. Land Use Considerations

Private ownership, operation, and maintenance, of BMPs would be suited to industrial and condominium developments. Concerns were expressed about private maintenance of BMPs. Some enforcement powers would be required in order for private ownership/maintenance of BMPs to become feasible.

- legislation to allow municipalities to bill landowners with maintenance costs if landowners do not provide adequate maintenance
- establishment of a public utility which collects fees to provide BMP maintenance

Group 2

Group 2 discussed this session by looking at the impediments to the approval of BMPs and possible improvements to the planning/approvals process.

Impediments to the Approvals Process

1. The lack of agreed upon criteria (both quality and quantity) with respect to watershed objectives.

2. There is an overlap of responsibilities between the reviewing agencies. All of the concerned agencies review the entire storm water management report and make comments on all aspects of the report.

3. There is a lack of knowledge amongst the reviewing agencies with regards to acceptable BMPs based on site specific conditions and downstream water uses.

4. The identification of water quality needs occurs too late in the planning process. Often, a BMP design is retrofitted to a site plan or secondary plan instead of being an integral part of the planning process.

5. There is a lack of public awareness on the need for BMPs, and a general lack of knowledge on the significance of urban non-point source pollution.

6. The reviewing agencies are apprehensive about making decisions which may set a precedent, involve taking risks, and involve assuming liability.

7. There is a lack of legislative authority to enforce compliance with storm water quality controls.

8. The engineer, planner, and reviewing agency do not carry out adequate field work to ensure that the paper design is feasible on site.

9. There is public apprehension concerning groundwater contamination, safety risks, and aesthetics associated with the implementation of BMPs.

Improvements to the Approvals Process

1. An amendment to the Planning Act requiring urban drainage planning of BMPs.

2. One of the reviewing agencies should take a lead or coordinator role in water quality requirements.

3. The planning/reviewing agencies must enhance their staff resources. This could be involve :
   - increasing staff
   - shifting staff from reviewing functions to planning functions
   - increasing the technical training of staff

4. A coordinated set of watershed objectives based on receiving water use must be defined. Water uses and primary parameters which affect water use (suspended solids, bacteria, nutrients, temperature) could be the basis of regional maps dictating areas of different water quality objectives/regulation.

5. Pilot studies of infiltration and wet pond operation in the Canadian environment.

6. Incentives could be provided to developers who implement BMPs such as faster approval times and parkland dedication.

7. A hierarchy of BMP techniques with respect to water quality criteria needs to be established.

8. Mandatory site visits should be required by both review staff and consultants.

9. Each reviewing agency's role, responsibility, and liability with regards to storm water quality should be clearly defined.

10. Monitoring of new BMPs should be made compulsory. The monitoring would provide feedback to the approval agencies on the appropriateness of the BMP for the given site. The monitoring could also be added to a common BMP monitoring database which could be referenced for new BMP approvals. The monitoring could be performed as a levy on development or by the conservation authority (provided they are given a mandate to monitor and the necessary funding).

11. It should be mandatory for an engineer to be on-site during construction to ensure environmental compliance with the design report.

12. A public awareness/education program should be initiated to address public concerns about BMPs and the need for urban non-point source controls.

13. Approvals staff should be encouraged to be receptive to new BMP designs. Alternatively, specific staff could be hired to review new idea approvals.

14. More approval functions should be delegated to the local municipalities and conservation authority.

6.7 <u>ENVIRONMENTAL ISSUES</u>

The goal of this session was to identify the environmental impact concerns of BMPs on receiving waters and the surrounding ecosystem.

Group 1

Minimum standards are required for all streams to protect the larger ecosystem. The efficiency of water quality measures used to maintain the minimum standards must be reviewed to determine whether this approach would be feasible on a provincial scale.

Watershed planning should define the water quality objectives in different parts of the watershed, and should help to set criteria for land use planning based on these objectives.

Successful BMPs provide downstream aquatic resource protection. The difference between a successful and an unsuccessful BMP is dependent on a myriad of site specific characteristics such as an aquatic species' low tolerance to pollution.

There cannot be non-impact development. Agencies must accept some realistic amount of environmental risk associated with urban development. There cannot be urban development without some water quality degradation.

There is a conflict amongst reviewing agencies concerning the use of dispersed BMP facilities as opposed to centralized BMP facilities. Dispersed BMPs are environmentally superior while centralized BMPs are more economical to maintain.

The use of BMPs in the valleylands conflicts with the goal of valleyland preservation. Table lands are reluctantly used for storm water management in Maryland. Environmentally sensitive areas must also be identified and avoided.

There are concerns over the use of man-made wetlands for storm water treatment. Constructed wetlands must be identified as man-made as opposed to natural or else they may become the subject of protection. In Maryland direct discharges to natural wetlands are not permitted. Primary treatment of stormwater is required before it can be discharged to a wetland.

Group 2

Group 2 discussed 3 main topics in this session :

- advantages/disadvantages of specific BMPs
- design philosophy and environmental impact
- individual designs for a specific development

Advantages/Disadvantages of specific BMPs

Wet Ponds

Advantages

- create wetlands (aquatic and wildlife habitat)
- prevent sediment from entering downstream watercourse
- support warm water fisheries
- local amenity to adjacent homeowners

- requires a large area (lowers ultimate development density if not located in dedicated parkland)

Disadvantages
- additional maintenance costs
- destroys wetlands (permanent pool alters hydrological and ecological regime)
- provides thermal warming of storm water
- sediment disposal problems
- trapped sediment is potentially toxic
- perceived problem with mosquitos, odour, garbage, and algae
- barrier to fish migration
- wildlife nuisance to adjacent homeowners
- requires a lot of property (loss of developable land)

Extended Detention Dry Ponds

Advantages
- reduces downstream erosion
- has multi-purpose use (eg. baseball)
- provides flood control
- provides some chemical and sediment control

Disadvantages
- limited groundwater recharge
- not as effective as other BMPs (eg. wet ponds, infiltration) with respect to sediment and nutrient removal
- moderate temperature increase
- mosquito and odour problems
- body contact with sediment
- sediment disposal problems
- no reduction in bacteria

Infiltration Techniques

Advantages
- ground water recharge
- low flow stabilization
- good pollutant removal (based on U.S. research)
- small area required

Disadvantages

- ground water contamination
- need appropriate soils and water table conditions
- high maintenance costs
- difficult to monitor effectiveness
- poor track record with respect to failures

Design Philosophy with Respect to Environmental Impacts

Three main issues were discussed with respect to the consideration of the environment during urbanization :

- the goal of "sustainable development"
- the preparation of broader "blue book" guidelines which would address storm water quality
- a change in attitude to regard water as a resource instead of a problem

The term "sustainable development" was questioned with regards to its precise meaning. The consensus was that the toxic threshold for storm water pollutants in the particular watercourse would have to be identified, and that the ultimate development planning would have to be based on those limits.

There was considerable disagreement within the group on whether the goal of water quality controls should be to :

- minimize environmental impacts
- maintain ambient environmental conditions
- or improve environmental conditions

Half of the group argued that the nature of development alters the watershed hydrology, and that water quality measures cannot completely mitigate this fact (ie. no BMPs are 100 % effective, therefore environmental improvement through development is impossible). The other half felt that water quality measures could improve conditions within the watercourse (eg groundwater recharge, wildlife habitat).

BMP Design for a Specific Development

A specific design problem was posed to the members of the group who were asked to suggest a BMP solution for water quality enhancement/mitigation.

Development Site

The site to be developed was 125 ha in size. The proposed development was condominiums. The post development level of imperviousness was approximated at 25 %. The site was classified as having good soils (good drainage).

The proposed site drained into a cold water stream along a 2 km length. A 10-15 metre vegetated buffer strip with good shading lined the banks of the stream.

The site was located near the headwaters of the creek. Upstream of the site was 300 ha, 50 % of which was forested. The remainder of this land was used for agricultural purposes.

BMP Solutions

Most people tended to use infiltration in their BMP solution due to the thermal effects associated with wet ponds. A combination of infiltration and wet ponds/extended detention wet ponds was used by some people since infiltration techniques are generally only applicable for areas less than 5 ha in size. Although a wide range of BMP solutions were derived, the solutions were not rated. The best environmental solutions were also the most expensive in terms of operations and maintenance.

For the sake of brevity, only one of the proposed solutions is provided in detail.

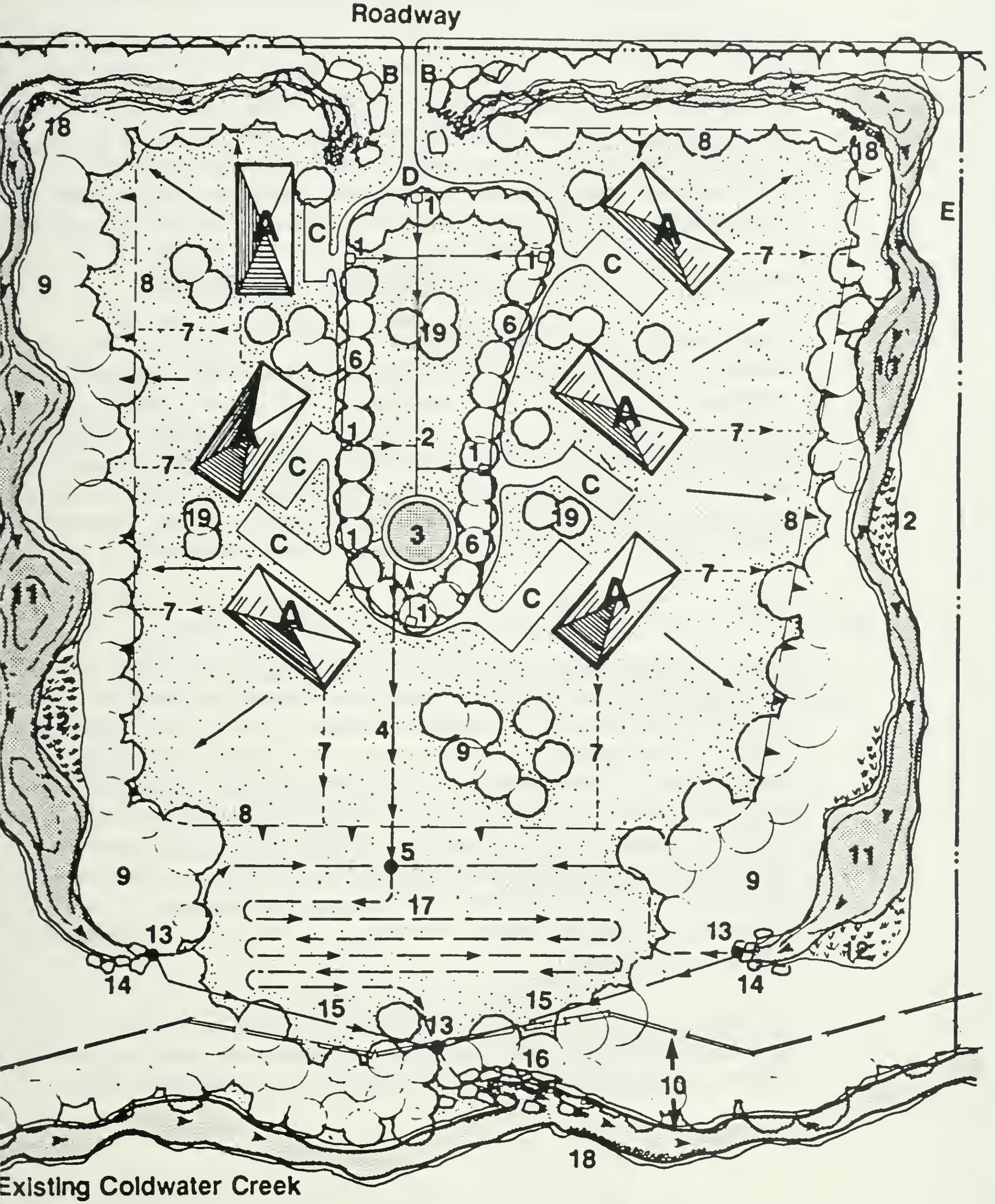
WORKSHOP MODEL – STORM WATER QUALITY ENHANCEMENT SYSTEM ON A MEDIUM DENSITY RESIDENTIAL SITE

Refer to Figure 6.8– Workshop Model

Key

A	–	Cluster Condominium Units
B	–	Entry Features
C	–	Parking Areas
D	–	Entry Road
E	–	Property Limit
1	–	Catchbasin with Oil/Grit Separator
2.	–	Connector Pipe - Stormwater
3.	–	Settlement Sump - Fountain Feature
4.	–	Connector Pipe to Infiltration System
5.	–	Orifice Control/Clean Out
6.	–	Grassed Swales
7.	–	Downspout Leaders Connecting to Grassed Swales
8.	–	Spreader Swale
9.	–	Filter Strip - Existing Woodlot and Proposed Plantings
10.	–	25m Buffer Zone at Existing Stream
11.	–	Elongated Wet Ponds with Vegetative Cover
12.	–	Wetland Pockets
13.	–	Natural Stone Outlet to Infiltration System
14.	–	Orifice Control/Clean Out
15.	–	Overflow Pipe
16.	–	Natural Stone Outfall with Boulder Chute Blocks
17.	–	PVC/Filter Fabric Infiltration System with Open Space Recreation Field Surface
18.	–	Riverstone Erosion Control
19.	–	Supplementary Planting

Refer to Text for Description



Workshop Model Figure 6.8

SYSTEM DESCRIPTION

The proposed development was blocked into smaller clusters to minimize impact on the site. Existing tree stands were preserved where feasible. The development was sited as far away from the existing cold water stream as possible to provide a wide buffer between it and the stream. Runoff is treated in two separate systems - one handles runoff from road and parking areas, the other, relatively clean runoff from roof top and lawn areas.

System One — The system treating paved areas works is described below.

Runoff from parking areas and road surfaces travels through grassed swales to catch basin/oil grit separators. Swales remove heavy suspended solids, oil grit separators remove hydrocarbons and finer grit. Storm water flows through connector pipes to a central sedimentation sump. The surface waters of this sump also act as a feature fountain for the central court of the site. Treated water from the sump travels down a connector pipe to the P.V.C. infiltration system. An orifice control at each end of the system and moderates flow for maximum infiltration and provides access for cleanout. Overflow pipes allow the system to be fully or partially by-passed in severe runoff events.

System Two - The system treating surface runoff on grassed areas.

System two treats surface runoff through a series of vegetative B.M.P. systems. Runoff is directed through grassed swales to a grassed spreader swale and distributed through woodlot filter strips consisting of existing vegetation in combination with supplementary plantings. Water percolates through the filter strip and is intercepted by a longitudinal detention pond with wetland pockets. Suspended solids and soluble pollutants are treated. Water discharges from the ponds into the P.V.C. infiltration system through natural stone outlets. Pond depths are varied and shorelines articulated to encourage the establishment of a variety of aquatic and terrestrial wildlife habitats. Riverstone is used instead of gabion and rip rap to control erosion. Pond edges are heavily planted to control water temperature. All mechanical systems are constructed in a natural form with stone or are concealed with plantings.

This model illustrates how a development can be designed at the conceptual stage to accommodate storm water quality requirements and integrate with existing site conditions to protect an adjacent sensitive cold water stream from the effects of development.

6.8 OPERATIONS, MAINTENANCE, AND PUBLIC CONCERNS

The goal of this session was to identify the operations and maintenance concerns regarding BMPs and the public acceptance of BMPs.

Group 1

Group 1 discussed four major issues in this session :

- maintenance requirements for different types of BMPs
- public safety and liability concerns
- responsibility for maintenance
- BMP compatibility with adjacent land uses

Maintenance Requirements of Various BMPs

1. Oil/Grit Separators
   - very high cleanout frequency (2-3 times per year) catch-basin frequency is once every 3 years
   - expensive cleanout cost ($1500/time - vacuum truck)
   - additional treatment is required (truck disposes of effluent at sewage treatment plant)

2. Infiltration Methods
   - pre-treatment requirements essential (plunge pool, grassed waterways/buffer strip, or oil/grit separator required)
   - eventually need to re-construct at least part of infiltration facility due to sediment accumulation (lifespan of infiltration facility depends on loading, pre-treatment measures, sediment control during construction, etc)

3. Extended Dry Detention Ponds
   - frequent sediment removal (+2 times/year)
   - requires grass cutting
   - establishment and maintenance of marsh plants
   - must have separate land dedication (not feasible in the 5% parkland dedication)

4. Wet Ponds
   - very expensive to dredge pond for sediment removal
   - requires draining for removal of sediment
   - use of sediment forebay facilitates sediment removal (forebay must be cleaned out frequently)
   - disposal problems with sediment due to its toxic nature

- wet ponds become large, and expensive (land cost), when they must provide quantity control as well as quality control
- maintenance costs are higher for many localized wet ponds compared to large regional facilities
- concern regarding conversion costs from dry ponds to wet ponds
- information from Maryland indicates that maintenance fees in a condominium ownership of a BMP range from $5-$20 per month

5) Extended Detention Wet Ponds
- probably higher sediment removal costs than wet ponds due to greater sediment capture
- problems in Maryland with muddy water in extended detention wet ponds

Public Safety and Liability Concerns

In Maryland, safety is treated as a design issue. Design features such as fencing along the top of the slope, and benching around the shoreline of the permanent pool are built in to ensure public safety.

The depth of the permanent pool is not regarded as a safety problem in Maryland. Groundwater contamination from BMPs is an issue which could potentially be a problem in the U.S. in the future.

If public safety/liability is a major issue in a specific development, a waiver system could be used whereby fees would be paid for the construction of a regional facility, in lieu of constructing localized BMPs.

Bill 20 if passed, provides for levy charges for maintenance of storm water facilities starting in 1991. This bill if passed into law could preclude the collection of future maintenance fees.

Maintenance Responsibility

There was a consensus that the developer would be initially responsible for the operation and maintenance costs of a BMP.

The long-term maintenance of a BMP was determined to be either the responsibility of the municipality or the private sector.

The private sector can include easements and has the financial resources to provide

maintenance. Private maintenance of industrial areas has been successfully applied in Ontario.

The province would like to see the municipality own and maintain the storm water facilities to ensure accountability. Funds could be expropriated from the developers to pay for this maintenance. A contract, or some legislative enforcement, would be required between the developer and the municipality, since the commitment of a developer would diminish once the municipality assumed the facility.

Funding of BMP maintenance through taxes is another option. Unfortunately, provincial requirements are already about to increase taxes by 45 %.

Developer funding of BMP maintenance would be passed along to new home buyers, providing an addition burden to the high cost of living.

Compatibility with Adjacent Land Uses

1. Surface Area Requirements
   - wet ponds require the largest surface area
   - infiltration trench has a high compatibility with recreation/parkland and requires a small surface area (due to the small drainage area it serves)
   - water quality inlets require a minimal amount of surface area

2. Other Issues
   - wet ponds provide recreational benefits (boating, visual appeal)
   - extended detention dry ponds provide very limited recreational use
   - wetland marshes are educational in nature providing an insight into biological processes (cattails, frogs)
   - infiltration facilities are compatible with recreational uses

Group 2

Group 2 discussed the responsibility for operation and maintenance of BMPs and discussed municipality concerns regarding storm water facilities.

The discussion on responsibility for operation and maintenance of BMPs centred on the appropriateness of the local municipality providing this function. All members of the group agreed that the concept of a maintenance-free design was unrealistic, and counter-productive to the intent of BMPs.

Advantages and Disadvantages of BMP Maintenance provided by Municipality

Advantages

- municipalities are the most efficient at maintenance
- municipalities are closest to the problems
- municipalities are the most accountable to the public
- private maintenance is not always done properly
- lack of enforcement with private maintenance

Disadvantages

- not within a municipality's mandate to look after storm water management facilities
- municipalities lack funding/staff to provide maintenance functions
- municipalities lack the technical expertise to ensure proper operation/maintenance of storm water management facilities

Other Methods of Providing/Ensuring Maintenance

- Set up a separate public utility to handle maintenance
- There is the potential for the conservation authority or the Regional Municipality to handle the operations and maintenance of BMPs
- In industrial/commercial areas locate ponds up front to ensure maintenance compliance

Although it was recognized that the developer would provide initial funding and maintenance for BMPs there were concerns regarding the length of time the developer would be responsible for the BMP. Sediment removal and structural repairs occur after a lengthy period of time (probably after the developer has been released from his/her responsibility).

The only solution for this problem would be to lengthen the responsibility period of the developer (+10 years). The developer would be responsible for effectiveness of the BMP, and its maintenance during this period. The level of effectiveness would have to be defined during the planning and approvals process.

Municipal Survey

The City of Scarborough representative distributed a survey, which was originally distributed to Ontario municipalities, concerning maintenance and operational problems with storm water facilities. The survey results from group 2 are shown along with the actual survey responses in Table 6.5.

A direct comparison between the survey results is not possible since fewer questions were rated by the municipalities as opposed to the group members. The survey does indicate that the municipalities felt that the everyday maintenance (grass cutting) was of prime concern. Group 2 tended to prioritize pollutant problems such as sedimentation and pollutant removal, and regarded the everyday maintenance (grass cutting) as of little concern.

Table 6.5. Municipal Survey Results

Problem	Municipality	Group 2	Adjusted Group 2
Mosquito Control	5	10	7
Sedimentation	3	1	1
Bank Deterioration	4	4	2
Weed Control	1	5	3
Outlet Stoppage	6	5	3
Algal Growth	7	6	5
Grass Maintenance	2	7	6
Fence Maintenance	NA	11	NA
Pollutant Disposal	NA	2	NA
Cost Increase	NA	3	NA
Replacement of BMP	NA	9	NA

6.9 RESEARCH NEEDS / PILOT STUDIES

The goal of this session was to identify areas requiring research and necessary pilot studies.

Group 1

Group 1 defined research as practical application studies. To define the research needs Group 1 reviewed the existing state of BMP/urban water quality technology.

Questions on existing technology

- is existing knowledge of BMPs sufficient for implementation in Ontario ?
- is there a database on monitored sites/efficiencies ?
- do we know enough about different land uses ?
- do we know enough about seasonal vs annual runoff volumes ?
- do we know enough about water quality parameters ?
- do we know enough about the treatment of dissolved versus suspended pollutants ?

Research on Urban Water Quality and BMP Knowledge

There is a reasonably good knowledge base concerning the quality of urban runoff and the transport of pollutants. The knowledge base of BMP operation under summer conditions is also adequate.

There is a lack of sufficient knowledge of BMP operation under winter/snowmelt conditions. Processes such as pollutant accumulation, first flush in snowmelt, and groundwater transport need to be studied.

More research is needed on dissolved versus suspended pollutants. Treatment of suspended pollutants, such as sediment, requires only settling. Road salt, used to de-ice roads in Ontario, dissolves in water releasing chlorides. Treatment of dissolved substances such as chlorides requires more complex processes than settling alone.

More knowledge is required on the size distribution of suspended solids versus the associated chemical transport to determine optimal settling times.

There is a smaller knowledge base on industrial storm water quality. The MISA (Municipal Industrial Strategic Abatement) program will probably increase the amount of knowledge in this area.

The relationship between time of concentration versus first flush of pollutants should be analysed on a watershed scale. This would provide information on the size of the first flush for a watershed and indicate the limiting size of the contributing area to a BMP.

Research on BMP Design

Research is required on BMP design for Canadian conditions/climate. Specific areas of interest include :

- winter/spring operation and groundwater fluctuations
- effects of ice cover
- outlet structure design and operation to avoid flows bypassing outlet control under ice conditions and ice pressurization at the outlet structure.
- effects of chlorides

Research on BMP Effectiveness

There is existing data on BMP effectiveness in the U.S. from the NURP study. Pilot projects are still required in Canada to determine BMP effectiveness under Canadian climatic conditions.

There is a need to determine the actual impact of BMPs on the downstream ecosystem. If research indicated that BMPs could preserve the downstream ecosystem, BMPs would gain greater acceptance from the public and municipalities.

Research is required concerning the true operations and maintenance costs of BMPs.

Research on Performance Data

Routine monitoring of water quality parameters should be performed on new BMP installations.

Mass loading research studies should be undertaken to determine relationships between rainfall, BMP inflow, sediment, biota uptake, BMP outflow, and BMP clean out. Bio-monitoring should be carried out in conjunction with the mass loading studies at points upstream, within, and downstream of the BMP.

Standards are required for monitoring methods with regards to storm water pollutants. This will ensure that regional databases contain consistent information.

The appropriateness of standard BMP design features needs to be addressed. A set of standard design features would facilitate the approvals process.

The compliance of a BMP in meeting efficiency standards should be defined using confidence limits.

Research should be conducted on other devices such as swirl concentrators and processes such as flocculation. Information from the U.S. should provide a solid background in these areas.

Research needs to be performed on innovative devices designed to reduce the maintenance needs of BMPs.

Pilot Facilities/Projects

Types of BMPs Requiring Research

- Wet Ponds/Extended Detention Wet Ponds
- Infiltration (various types)
- extended detention dry ponds
- constructed (man-made) wetlands
- soft BMPs (difficult to monitor)

Group 2

Group two focused on two types of BMP which require further research for Canadian conditions.

Infiltration

- several pilot studies with different pre-treatment techniques (grass swale, oil/grit separator)
- operation above the frost line under snowmelt conditions
- potential for groundwater contamination by soluble pollutants such as chlorides
- research on infiltration techniques below the frost line

Wet Ponds

- mass balance monitoring
- temperature monitoring (influent and effluent)
- winter monitoring (ice and snowmelt)
- data on bacterial removal and sediment toxicity
- refine performance data from other areas to Ontario conditions
- review hydrologic design criteria

The group agreed that the hydrologic design criteria and the infiltration design criteria in general from the states is not transferable.

Other areas of research were also identified :

- re-suspension of pond sediment
- bio-accumulation of urban pollutants
- thermal stratification within ponds
- validity of water quality sampling techniques

The need for an adequate data management system was recognized as of prime importance. Although quality data is monitored, it is usually not stored in an accessible or transferable format. There is a need for an agency to compile storm water quality data from across the province to provide a common database for planning/approval agencies. Common databases are required for the following areas of interest :

- BMP inventory including physical characteristics and sources of pollutants
- stream classifications
- analytical standards and sampling protocol
- long term effects
- BMP maintenance (frequency, costs, type)
- public acceptance/concerns

The compilation of these databases requires a continual commitment since they will need to be frequently updated for new facilities, additional monitoring, and changing watershed conditions.

There was a consensus that an extensive monitoring program on numerous sites was not required. Extensive monitoring on two or three projects was deemed to be more beneficial. The long term impacts of urbanization could be determined by monitoring a watershed from the pre-development condition (rural) through the different phases of urbanization to the completely developed condition.

The administration of the research projects was discussed. The group determined that the MOE and MNR should fund the research projects while the conservation authority or municipality disseminate the resulting information. The group indicated that the provincial government should employ a BMP specialist to coordinate the research projects and give advice to the conservation authorities and local municipalities.

Pilot Projects

Several pilot monitoring projects were identified by the group:

Markham Ponds
Catfish Pond
G. Ross Lord Reservoir
Fanshawe Reservoir
Newport Infiltration Trench
Seaton Pond
York Region Police Park
Brentview Heights Extended Detention Pond with Marsh
Pickering Plains Infiltration Basin and/or Wet Pond
Cache Woods Infiltration Trench

Appendix E

MUNICIPALITY SURVEY

A two page survey was sent to municipalities with a population greater than 30,000. A copy of the survey is provided at the end of this appendix. A total of 56 municipalities were identified in this category.

Municipalities with a Population > 30,000

Aurora	North Bay
Barrie	North York
Belleville	Oakville
Brampton	Orillia
Brantford	Oshawa
Brockville	Ottawa
Burlington	Owen Sound
Caledon	Peterborough
Cambridge	Pickering
Chatham	Richmond Hill
Cornwall	Sarnia
East York	Scarborough
Etobicoke	St. Catharines
Flamborough	St. Thomas
Fort Erie	Stoney Creek
Gloucester	Stratford
Guelph	Sudbury
Halton Hills	Sault Ste. Marie
Hamilton	Thunder Bay
Kanata	Timmins
Kingston	Toronto
Kitchener	Vaughan
London	Waterloo
Milton	Windsor
Nepean	Welland
Newcastle	Whitby
Newmarket	Woodstock
Niagara Falls	York

Twenty-nine of the fifty six municipalities responded to the survey representing a 52 % return rate. The results from the survey are summarized in Section 2 of the main report.

STORM WATER QUALITY ENHANCEMENT FACILITIES QUESTIONNAIRE

1. Do you have any storm water quality enhancement facilities in your municipality ? Yes ___ No ___
(ie. Wet ponds, infiltration basins, porous pavement, extended dry detention ponds, etc. ; **Please refer to the attached glossary if any terms are unfamiliar)**

If you do not have any water quality facilities please go to question 13

2. How many water quality enhancement facilities are currently in operation in your municipality ?

	Number
Wet Ponds	___
Extended detention dry ponds	___
Infiltration Basins	___
Infiltration Trenches	___
Porous Pavement	___
Constructed Marshland	___
Underground Tanks	___
Vegetated Buffer Strips/Grassed Swales	___
Oil and Grit Separators	___

3. Please specify the location, drainage area, and appropriate characteristics for each water quality facility

Facility Type	Years in Operation	Location	Watercourse
___	___	___	___
___	___	___	___
___	___	___	___

4. Do you maintain your water quality facility ? Yes ___ No ___

If 'YES' to what extent ?

Facility Type	Type of Maintenance	Maintenance Interval	Maintenance Cost
___	___	___	___
___	___	___	___
___	___	___	___

5. Have you monitored the performance of any water quality enhancement facility ? Yes ___ No ___
(ie. tested storm water quality entering and/or discharging from the facility ?)

If you have not monitored the storm water quality from any facility please go to question 7.

6. Please provide the following information concerning any facility where you have monitored the storm water quality ?

Type of Facility	Location	Number of Years of Monitored Data	Data Storage Media: Hardcopy	Data Storage Media: Computer
___	___	___	___	___
___	___	___	___	___
___	___	___	___	___

7. How many stormwater quantity ponds are present in your municipality ? ___

8. How many storm water quantity detention ponds have been retro-fitted for water quality enhancement in your municipality ? ___

9. Do you have any reports or plans/photographs/maps which detail the design of any water quality enhancement facilities ? Yes ___ No ___

10. What storm water quality problem(s) was identified during the design of the facility ?

Bacteria	________	Toxic Chemicals	________
Nutrients	________	Thermal Effects	________
Sediments	________	Chlorides (salts)	________
Oil and Grease	________	Aesthetics	________
Trace Metals	________	General Concern	________

11. How effective have your storm water quality features been in enhancing water quality ?

Effective	________
Make No Difference	________
Not Effective	________
Don't Know	________

12. Please provide the name and telephone number of the person who should be contacted for further information regarding stormwater quality enhancement facilities.

Name ________________________ Telephone Number ________________________

13. How many planned or proposed storm water quality enhancement facilities are currently being considered for implementation ? ___

14. What are the major perceived/realized drawbacks and/or problems with storm water quality enhancement facilities ?

____
____
____
____
____

15. Does your municipality support the implementation of natural water quality enhancement facilities such as infiltration trenches, wet ponds, etc. ? Please give reasons.

____
____
____
____
____

Appendix F

Advantages and Disadvantages of Different BMPs

The following section describes the advantages and disadvantages of different BMPs. For convenience, it has been divided into structural and non-structural techniques.

Because the focus of this review is on the environmental aspects of BMPs, little emphasis has been placed on advantages or disadvantages relevant to maintenance or cost aspects, except as they relate to environmental effects. For example, periodic dredging operations in retention ponds can result in the release of sediments and other contaminants, and disturb benthic organisms.

It should be noted that no distinction has been made between real advantages and disadvantages and perceived advantages and disadvantages. For example, "nuisance problems", usually meaning either odour or mosquito problems, are often listed as disadvantage. Usually, if a system is well-designed and well-suited for its location, then these problems will be either minimal or non-existent.

The following does not examine temporary erosion and sediment control measures such as those which may be implemented during construction activities (eg. straw bales, mulching, hydroseeding, etc).

1. Infiltration Basins

Advantages

- attenuates peak flows
- provides groundwater recharge
- groundwater infiltration moderates temperature fluctuations
- can effectively remove pollutants if well-designed
- allows settling of sediments
- some streambank erosion control
- can provide temporary habitat for waterfowl when wetted
- low capital cost
- because sediment removal during maintenance can occur under dry conditions, little impacts on wet areas
- since infiltration systems reduce surface runoff, storm drain systems can be downsized

Disadvantages

- does not create permanent habitat
- potential/perceived nuisance problems
- can result in infiltration of contaminated water
- in the case of large storm events, water is passed via an overflow resulting in poor pollutant removal (may be an unavoidable problem)
- high failure rate due to problems with site conditions, design, construction, and lack of maintenance
- potentially high maintenance if fine silts affect infiltration
- moderate maintenance costs associated with sediment removal from the associated settling basin
- may not be considered aesthetically appealing
- potentially ineffective during spring period

2. Retention Basins

Advantages

- creates permanent habitat suitable for some species
- if constructed on-line, may have some benefits to warmwater species
- if constructed off-line, does not form a barrier to migration for many fish species
- attenuates peak flows
- provides recreational benefits
- provides aesthetic benefits
- potentially very effective removal of pollutants
- allows settling of sediments
- some streambank erosion control
- because they are permanently wetted, can develop into diverse habitats supporting a wide range of species including birds, mammals, etc., in addition to fish
- often wetland habitats are created in certain areas
- wetland vegetation further improves uptake of contaminants and nutrients
- can be designed to capture first flush
- buffers around border of basins can be planted for wildlife habitat
- can serve large areas
- is cost effective

Disadvantages

- provides only limited groundwater recharge
- may lead to contamination of fish and wildlife through food-chain effects
- periodic maintenance is disruptive to biological communities (even though maintenance is essential)
- if constructed on-line wet ponds can act as barriers to migration
- their construction can destroy previously-existing habitat
- impounded water can become excessively heated with negative impacts on some aquatic species
- maintenance activities may result in the release of silts and contaminants
- can lead to stream (and therefore habitat) changes by changing existing hydrology
- cumulative hydrograph impacts of many ponds along the waterbody can lead to increased flooding problems
- if designed to shave peaks, then the period of time that banks in areas downstream of the structure are wetted can be increased leading to bank instability and erosion with consequent effects on habitat
- if excessively eutrophic or thermally stratified, water can become anoxic occasionally during summer months - the outfall can therefore discharge anoxic water into the receiving water bodies (negative impact on stream ecology, odour problems, nutrient cycling from sediments)
- maintenance may be costly if dredging is required
- requires a large area of land for implementation
- wildlife nuisance to adjacent homeowners

3. Extended Detention Basin

Advantages

- provides flood control
- reduces downstream erosion
- effective removal of particulate pollutants
- can provide some low (base) flow augmentation for several days following storm events
- lower portion of pond can be designed as a shallow wetland resulting in habitat creation suitable for warmwater fish species as well as other forms of wildlife
- where lower portion of pond has been designed as shallow wetlands, removal of some dissolved pollutants can be enhanced
- can be designed to capture first flush

- buffers around border of basins can be planted for wildlife habitat
- relatively low cost/cost effective
- can serve large areas
- has multi-purpose use (recreation-baseball)

Disadvantages

- pollutant removal efficiency dependent upon designed detention period
- detained water is susceptible to solar heating and during release can have negative effects upon natural stream communities
- depending upon the duration of the detention period, removal of soluble pollutants and bacteria may poor
- may not create permanent habitat
- where limited habitat is created, it is rarely suitable for coldwater species
- limited groundwater recharge contributions
- can lead to stream (and therefore habitat) changes by altering existing hydrology
- may lead to contamination of fish and wildlife through food-chain effects
- potential nuisance problems (odour, mosquitoes)
- requires a large area of land for implementation

4. Infiltration Trench

Advantages

- enhances groundwater recharge (groundwater recharge is critical in headwater areas)
- helps to minimize changes to natural hydrograph
- helps maintain base flows
- helps to moderate temperature fluctuations
- provides essential groundwater influx for spawning habitat for coldwater certain species, especially salmonoids
- assists with maintenance of groundwater levels
- effective contaminant/pollutant removal
- provides some moderation of peak flows during small events
- by reducing peak flows, reduces erosion flows
- since infiltration systems reduce surface runoff, storm drain systems can be downsized

Disadvantages

- does not directly create habitat
- risk of groundwater contamination
- not designed to remove coarse particulates (requires pre-treatment)
- potentially high maintenance costs
- high failure rate due to site, design, construction, and/or operational and maintenance problems
- not suitable for large areas
- short life span
- not suitable for control of peak flows during large events
- may be ineffective during spring period

5. Porous Pavement

Advantages

- attenuates peak flows during small events
- improves erosion control
- provides some groundwater recharge and by doing so contributes to maintenance of base flows and to temperature modulation
- since infiltration systems reduce surface runoff, storm drain systems can be downsized

Disadvantages

- does not create habitat
- risk of groundwater contamination
- high failure rate
- potentially high maintenance costs
- short life span
- not suitable for large areas
- not designed to remove coarse particulates

6. Oil/Grit Separator

Advantages

- provides some pre-treatment of run-off before it is discharged into infiltration systems, retention/detention systems, or into sewers discharging directly into aquatic systems
- compatible with storm drain network

Disadvantages

- no direct provision of habitat
- ineffective removal or treatment of some pollutants/contaminants
- high maintenance requirements
- not suitable for large areas
- ineffective for erosion or flood control

7. Grass Swale

Advantages

- slows surface flows
- encourages infiltration and therefore groundwater recharge
- provides greater opportunity for evapo-transpiration
- moderate improvements in water quality by removal of particulates
- some removal of nutrients by vegetative uptake
- applicable to many urban development situations
- an excellent "soft" BMP technique which can be easily combined with other BMPs
- low cost
- if well-located, very little maintenance

Disadvantages

- limited to gently sloping areas
- does not directly create habitat
- may pose nuisance problems
- limited treatment/removal of pollutants other than sediments
- ineffective during spring period
- ineffective for large areas or end-of-pipe solution

8. Artificial Wetland

Advantages

- very effective removal of sediments and contaminants
- very effective nutrient removal
- directly creates habitat suitable for a broad range of species including warmwater fish species, birds, mammals, etc.
- natural wetlands are important groundwater recharge areas, therefore, well-placed artificial wetlands may have the same effect
- assists with stabilization of base flows
- augments base flows
- can be designed to capture first flush

Disadvantages

- maintenance removal of sediments and contaminants can cause their release
- if created in an on-line situation, can have negative impacts on migration of some (coldwater) fish species
- possible thermal effects due to solar heating
- may lead to contamination of fish and wildlife through food-chain effects
- potential nuisance problems
- artificial wetlands, if placed in headwater areas, can damage the ecology of sensitive aquatic communities
- if excessively eutrophic, water can become anoxic occasionally during summer months - the outfall can therefore discharge anoxic water into the receiving water bodies (this can negatively impact stream ecology, lead to odour problems, and lead to nutrient cycling from sediments)
- ineffective during spring period

9. Buffer Strips

Advantages

- suitable for small areas
- effective in filtering out sediments
- somewhat effective in controlling velocity and erosion
- effective in maintaining water temperature
- somewhat effective in the uptake of pollutants

- stream bank stabilization
- excellent potential for integration into most site plans - compatible with most land uses as: parks and open space, buffer plantings, and trail systems/recreational uses
- high social acceptance
- effective in habitat creation
- minimal maintenance requirement
- minimal nuisance problems

Disadvantages

- not suitable for large areas or end-of-pipe solutions
- ineffective during spring period
- ineffective for peak flow control during large events

10. Filter Strips

Advantages

- effective in filtering out suspended solids
- effective in intercepting precipitation
- encourages a degree of infiltration depending on soil type
- creates habitat for wildlife (wooded filter strip) or passive recreation opportunities (grassland)
- minimal nuisance problems
- high potential for integration into most developments as buffer, open space, wooded edge, lawn or yard

Disadvantages

- requires maintenance of spreader to ensure proper performance
- not effective in freeze/thaw conditions
- not suitable for large areas or end-of-pipe solutions
- ineffective for peak flow control during large events

11. Seepage Trenches

Advantages

- increases infiltration/groundwater recharge
- helps to moderate stream temperature
- can significantly reduce surface runoff thereby contributing to reduced peak flows
- if undertaken on a large (subdivision or (clean) industrial park scale) infiltration systems significantly reduce surface runoff thereby possibly allowing downsizing of storm drain systems

Disadvantages

- no environmental disadvantages unless sites where contaminated runoff can be infiltrated (air pollution - atmospheric deposition)
- potential for creating basement wetting problems through interaction with foundation drains

12. Conservation of Existing Site Features (i.e., Woodlots and/or Supplementary Mass Planting)

Advantages

- effective interception of precipitation and runoff
- effective absorption, detention and infiltration of runoff
- maintenance of water temperature (canopy)

Disadvantages

- None